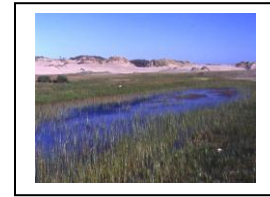




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**CALIFORNIA SEA-BLITE (*Suaeda californica*)
REINTRODUCTION PLAN,
SAN FRANCISCO BAY, CALIFORNIA**

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prepared for

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California sea-blite (*Suaeda californica*) colony established on natural shell beach, Pier 98, San Francisco. March 2006.

SUMMARY

California sea-blite (*Suaeda californica*), a salt-tolerant, fleshy-leaved coastal wetland shrub (traditionally Chenopodiaceae, goosefoot family; now placed in the Amaranthaceae), is a federally listed endangered species. It is native to only two localities, Morro Bay and San Francisco Bay. The primary natural habitat of California sea-blite is a very narrow high tide zone along sandy salt marsh edges or estuarine beaches. California sea-blite appears to have been naturally rare in San Francisco Bay, according to the earliest reliable botanical records. Most historic localities of the species in San Francisco Bay were from shorelines now incorporated in the East Bay (Oakland to Alameda), and the bay shore of the San Francisco Peninsula. The original native San Francisco Bay population became completely extirpated around 1960. The Morro Bay population size fluctuates, but it is distributed extensively and plants are usually vigorous. California sea-blite is readily propagated by seed and vegetative clones (rooted cuttings), and can be maintained in short-term cultivation in the coastal zone.

California sea-blite has a brief recent history of reintroduction to San Francisco Bay. Two pilot projects for reintroduction of California sea-blite to San Francisco Bay were implemented in San Francisco in 1999 at two newly constructed urban tidal marsh restoration sites: Crissy Field (National Park Service, Presidio of San Francisco) and Pier 98 (Port of San Francisco, Heron's Head Marsh; Figure 1). The pilot reintroductions utilized propagated clonal stock originating from Morro Bay (26 genotypes), provided to the National Park Service, Golden Gate National Recreation Area by the U.S. Fish and Wildlife Service. The original plantings suffered from adverse local environmental conditions in marsh restoration (choked tidal flows, prolonged flooding,). The Crissy Field population failed because of impaired tidal hydrology, and the original Pier 98 population declined because of unsuitable substrate. The Pier 98 reintroduction, however, resulted in several years of seed reproduction and apparently natural recruitment of a small population of highly vigorous California sea-blite on an adjacent small estuarine beach. The San Francisco Bay pilot reintroduction project history provides information about constraints, opportunities, and feasibility for regional reintroduction of the species in suitable tidal regimes and sandy/shell substrate.

In 2006, The Port of San Francisco and Golden Gate Audubon Society, in cooperation with the U.S. Fish and Wildlife Service, initiated a full-scale local reintroduction of California sea-blite to a reconstructed sand beach ecotone along a small urban salt marsh at Pier 94 (north of Pier 98), San Francisco. The founder population was grown from seed collected at Pier 98, and was planted along the high tide line in March 2006. In May 2006, all transplants survived and grew rapidly.

The principal goals and objectives for reintroduction of California sea-blite in San Francisco Bay are to establish persistent populations that reproduce and spread spontaneously within suitable habitats, with minimal active management. An important long-term objective of reintroduction is to establish populations that are composed mostly of naturally recruited (seedling-established) plants, rather than artificial transplants. A principal short-term objective of reintroduction is to establish small initial founder populations that survive and reproduce by seed, and increase in local population size. Long-term objectives also include cyclic population decline and regeneration in relation to natural disturbance events. The principal overall species conservation (recovery) goal for San Francisco Bay reintroduction is to spread the risk of the species' extinction between two geographically separate estuarine environments (San Francisco, Morro Bay) within the species historic range. Conserving two independent, geographically discrete estuarine populations is expected to offset the species' overall risk of extinction. Significant risks of catastrophic extinction that cannot be mitigated in Morro Bay alone include extreme Pacific storm erosion events, major oil spills, tsunamis, or rapid coastline changes.

Estuarine beaches composed of sand or shell fragments (shell hash) have naturally regenerated along some receptive urbanized shorelines of San Francisco Bay, within the historic geographic range of California sea-blite. Candidate sites for reintroduction of California sea-blite were screened evaluated as existing or potentially enhanced shoreline habitats. Selection of reintroduction sites is based on biogeography and ecology (historic range of the species, existing vegetation, prevailing dynamic ecological processes),

physical environment (beach and marsh dynamics, substrate, wave exposure, sediment supply, tidal litter deposition), and land ownership and management. Candidate sites were evaluated in terms of indicators of physical shoreline structure and dynamics (beach profile, wave climate, erosion/accretion, shoreline stability, tidal litter characteristics), invasive shoreline vegetation, land ownership and use (compatibility, management feasibility), and population potential. Four San Francisco Bay sites were considered highly feasible for reintroduction in near-term planning (one to three years): (1) Roberts Landing Beach (San Leandro); (2) Radio Point Beach marsh complex at Emeryville Crescent tidal flats (Oakland Bay Bridge approach, north shore), (3) Eastshore State Park beach, Berkeley; (4) Brisbane spit (bayshore gravel/shell spit south of Candlestick Point). Reintroduction plans for these sites are proposed.

Other potentially feasible locations for successful reintroduction of California sea-blite were identified, including (1) additional habitat at Pier 98, San Francisco; (2) India Basin Open Space beaches opposite Pier 98, San Francisco; (3) south Brisbane Lagoon; (4) east end of Crown Beach, Alameda; (5) Foster City beaches; (6) Redwood Point and southeastern Bird Island, Redwood City; (7) outer Bair Island shell beach ridges; (8) Whittell Marsh beach, Point Pinole Regional Park, Richmond (East Bay Regional Parks). These sites were considered to have one or more important uncertainties regarding physical or land use compatibility, and would require further investigation to determine whether they would be justified as high priorities for reintroduction. Preliminary conceptual reintroduction plans for these sites are outlined. Some potential reintroduction sites were considered to be relatively low in feasibility in the foreseeable future because of excessive erosion or excessive invasion by perennial wetland weeds.

Initiation of founder populations of California sea-blite is proposed by a process of (1) artificially propagating seedlings; (2) growing young (approximately 3 months to 1 yr old) plants of sufficient size to avoid high mortality risks; and (3) transplanting plants to receptive, suitable reintroduction sites and substrates. Transplanting must occur in wet, cool weather during late winter/early spring after peak high tides and storms have past. Timing and location (microhabitat site selection) of transplanting are important variables. Founder population size and density would be adapted to site-specific conditions, general principles of plant reintroduction, and a species-specific model of population structure based on Morro Bay surveys. Low mortality and rapid growth are expected by the end of the first growing season. Flowering and seed production are expected by the end of the second growing season. Seedling recruitment could potentially occur by the third growing season. Critical milestones for reintroduction success include spontaneous recruitment of seedlings, and survival of seedlings to reproduction.

The founder populations would initially need some maintenance, consisting mostly of removal of invasive shoreline weeds (principally Mediterranean saltwort, *Salsola soda*), until transplants approach mature size. Long-term population dynamics should require minimal or no maintenance, primarily control of non-native invasive vegetation. Reintroduced populations should be monitored for growth, survivorship, and seed production over at least 6 growing seasons. The level of monitoring effort should ensure continuity of monitoring, and may rely on trained volunteers. Basic monitoring of naturally recruited seedling populations (census, survivorship, growth, seed production) is also proposed.

Additional ecological restoration actions may increase the long-term viability of California sea-blite reintroduction in San Francisco Bay, and enhance its overall conservation value. Sand or shell sediment nourishment of sediment-deficient beaches (using sandy dredged materials otherwise placed as bulk fill or waste in other regions of the bay) in appropriate locations would increase potential habitat and population size. In addition, expanded estuarine sand beach habitat in central San Francisco Bay is likely to provide recovery benefits to other federally listed species (western snowy plover, Pacific population, California least tern), migratory shorebirds, and numerous rare or uncommon native plants species that depend on sandy high salt marsh or beach habitats.

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1.0 Introduction and Background

1.1. California sea-blite (*Suaeda californica*)

California sea-blite (*Suaeda californica*) is a federally endangered salt-tolerant sub-shrub endemic to coastal wetlands of San Francisco Bay and Morro Bay, California (Figure 1). California sea-blite was federally listed as endangered on December 15, 1994 (Federal Register 59, No. 240, 64612-64622). The species is not listed as endangered or threatened by the State of California. Morro Bay today supports the sole surviving natural population. In Morro Bay, it is threatened by dune destabilization, dredging and dredge disposal, competition with non-native invasive vegetation (especially ice-plant, *Carpobrotus edulis*), and catastrophic, stochastic disturbances to its very narrow shoreline distribution, such as extreme erosion (U.S. Fish and Wildlife Service 1994, and in prep.) Basic aspects of the ecology and life-history of California sea-blite are summarized below.

Taxonomy and morphology. California sea-blite is traditionally placed in the goosefoot or spinach family (Chenopodiaceae), like several of its associated native high salt marsh plants (pickleweed, *Sarcocornia pacifica*; Watson's saltbush, *Atriplex watsonii*; spearscale, *Atriplex triangularis*, syn. *A. prostrata*). California sea-blite is a low, decumbent (sprawling, spreading) shrub usually less than 0.5 m tall, and up to 2.0 m wide, with dense branches covered with fleshy, crowded, pale gray-green linear leaves up to 3.5 cm long (Figure 2). Prostrate or buried stems may form tangled masses that allow adjacent genetic individuals to coalesce into colonies, but true clonal spread (rooting of stems, physiologically independent individuals) has not been observed in natural conditions. Flowers of California sea-blite are small (2 to 3 mm diameter), green, radial, 5-petaled, and inconspicuously located in leaf axils close to the stem. Flowers usually occur among short axillary branches on second-year woody shoots (P. Baye, pers. observ.) below first-year vegetative growth near ends of branches (Figure 2). Viable seeds are small, black to brown, and have glossy seed coats; they are dispersed within buoyant, spongy small dry fruits.

Geographic distribution. Morro Bay, San Luis Obispo County, California, supports the last remaining natural population of California sea-blite. The historic range of California sea-blite in San Francisco Bay, the type locality of the species (Abrams 1944), was largely neglected in the listing of the species because it was already extinct there at the time of listing. The final rule suggested that "Elkhorn Slough in Monterey County is the only other remaining location considered to be potential habitat for *S. californica* on the California coast", in reference to its modern distribution. This statement referred only to habitat for existing wild populations, not recovery in suitable habitats within its historic range in San Francisco Bay.

According to late 19th century and early 20th century floras of California and the Bay Area, California sea-blite was rare in San Francisco Bay even before widespread filling and diking of bay marshes (Baye *et al.* 2000, Brewer *et al.* 1880, Behr 1888, Greene 1894, Jepson 1911). Its early historic rarity and association with sandy salt marshes suggests that it may have been a naturally rare relict coastal marsh plant species with former wider distribution, like *Solidago confinis* (also now extinct in San Francisco Bay, local in Morro Bay and Oso Flaco dune slacks, San Luis Obispo County; Baye, unpubl. data 1997-2002, Hoover 1970). Representative herbarium and flora records of all known historic localities of California sea-blite in San Francisco Bay are summarized in Table 1.

The last known records of California sea-blite in San Francisco Bay were reported around 1960; the date of extinction was presumably soon afterwards. Erroneous reports of California sea-blite in San Francisco Bay after 1960 are due to misidentification with *Suaeda moquinii* (Table 2) or unrelated species. The historic range of California sea-blite in San Francisco Bay has been thoroughly surveyed since 1991 to 2006, with focus on sand and shell beach ecotones and natural salt marsh levees, but no remnant populations have been detected (P. Baye, unpubl. data).

Modern habitats and associated vegetation. In Morro Bay, California sea-blite occurs almost entirely in a narrow zone (approximately 1 to 2 m wide) centered along the high tide line (highest drift-lines) of the Morro Bay sand spit (Figure 3), and the mainland eastern shoreline of Morro Bay. The high tide line position in which sea-blite typically occurs is indicated by drift-lines of eelgrass litter (*Zostera marina*, a submerged marine aquatic plant abundant in beds of Morro Bay). Above the high tide line on the west shore of Morro Bay, vegetation abrupt shifts to terrestrial coastal shrubs of dunes and dune seeps (emergent groundwater discharged from dune aquifers), including native *Eriophyllum staechadifolium* (lizard-tail), and non-native *Carpobrotus edulis* (iceplant; along stabilized dune edges), and annual and perennial forbs of estuarine beaches such as native *A. leucophylla* (beach saltbush), *Ambrosia chamissonis* (beach-bur) and non-native *Cakile maritima* (sea-rocket). Below the high tide line, estuarine wetland vegetation or bare sand shoreline dominates. Typical salt marsh plants co-occurring with California sea-blite include *Sarcocornia pacifica* (pickleweed), *Jaumea carnosa* (fleshy jaumea) and *Distichlis spicata* (saltgrass), and occasionally *Frankenia salina* (alkali-heath).

On the east shore of Morro Bay, California sea-blite occurs in sand bluff-toe habitats similar to backbarrier dune shorelines, and similar high salt marsh shorelines. It also occurs in extensive local shoreline stands merging with low-growing coast live oaks in paleodunes (“elfin forest” of stable Pleistocene dunes), even scandent into climbing into low oak canopies (P. Baye, unpubl. data, 1997-2002; U.S. Fish and Wildlife Service, in prep.).

Within the relatively sheltered tidal lagoon of Morro Bay, California sea-blite also occurs locally on substrates and habitats other than high salt marsh and estuarine sand beach. These atypical habitats account for a small proportion of the total population, but they reveal a great deal about the ecological amplitude of the species. They include: artificial (cultivated Japanese oyster) shell beach ridges (Figure 4); bases of sandy coastal bluffs (wave-cut scarps in paleodunes with seeps near sea level; Figure 5); and artificial boulder rip-rap (rock slope armor of marina interior and Morro Harbor entrance; Figure 6). The most extreme atypical habitat is at the shoreline beneath cormorant and heron rookeries of eucalyptus trees, with heavy deposits of guano (concentrations of urea, ammonia, nitrate toxic to most other shoreline plant species; Figure 5).

The range of the California sea-blite’s habitats in Morro Bay suggests the likely potential ecological range (habitat variability) of the species in modern San Francisco Bay. California sea-blite is absent on ocean beach high tide lines that support some of its associated species on the Morro Bay shore, such as *Cakile maritima*, *Atriplex triangularis*, and *Atriplex leucophylla*. Frequent high-energy beach erosion events, sand burial, and insufficient sand moisture (elevation above stable water table) are likely factors that restrict it on highly exposed beaches. California sea-blite is also absent in stable and active dunes adjacent to its main populations.

California sea-blite is generally absent in brackish tidal marshes edges of Morro Bay (Churro Creek delta, Los Osos Creek delta, and Shark Inlet). California sea-blite does co-occur with *Juncus acutus*, a brackish high marsh indicator, along the Baywood Park shoreline south of Sweet Springs. The scarcity or absence of California sea-blite in brackish marsh edges may be related to the dense, closed vegetation dominated by rushes, tules, and sedges, lack of erosional disturbances in sheltered shorelines where brackish marshes occur, and lack of significant eelgrass wracks.

Historic habitats. Historic habitats of California sea-blite in San Francisco Bay are generally described as sand beaches or salt marshes, or shore locations in the “back bay” (landward edge of the bay), habitats corresponding to prevailing contemporary habitats in which it occurs in Morro Bay (Table 3). Sand or shell beach edges of tidal marshes were widely distributed in central and south San Francisco Bay, including southeastern San Francisco (Goals Project 1999, Baye *et al.* 2000). Natural San Francisco Bay populations have been extinct since about 1960. Most records of past San Francisco Bay populations are from the former Oakland-Alameda salt marshes, including Bay Farm Island. Other historic San Francisco Bay localities include Berkeley, San Pablo Landing, and Palo Alto. The inferred Sonoma County (Petaluma) locality is almost certainly an erroneous report, based on misidentification of plant parts in adobe bricks that otherwise contain parts of only agrestal and ruderal non-native weed species (Table 2). The reported Warm Springs (Fremont) locality of California sea-blite in non-tidal subsaline wetland flats (Table 2), the typical habitat of *Suaeda moquinii*, is a misidentification of the latter species (P. Baye, pers. observ.)

Life-history, reproduction. Seedlings are narrowly associated with high-tide drift-line habitats in sand, organic tidal litter, or mixtures (Figures 3, 7). Plants with moderate to high vigor begin flowering and fruiting in the second growing season after seedling establishment. Fruiting shoots in Morro Bay typically produce very abundant seed; individual branches of mature plants can produce thousands of seed (P. Baye, pers. observ.) each year. Seeds are dispersed in buoyant dry fruits. Minimal seed dormancy exists, and seedling germination occurs in winter and spring during low-salinity, rainfall-influenced substrate conditions. Within colonies, neighboring mature plants produce large numbers of seed each year, on the order of thousands to tens of thousands of viable seed per plant. Seedlings germinate in nonsaline or low-salinity conditions at cool temperatures.

Isolated plants, outside of colonies, sometimes produce fewer viable seed than plants within small colonies of adjacent individuals. This suggests possible limitation of cross-pollination (Allee effect). Low seed production is also observed in small introduced populations in San Francisco (reduced to 4 plants at one colony, Pier 98; P. Baye, pers. observ. 2005).

The longevity of mature California sea-blite plants is unknown. Large, mature individuals, probably many years old (perhaps decades), were observed to persist at known locations over a five year period. Individual introduced transplants have persisted in San Francisco Bay for over 7 years, including plants stressed by adverse substrate at Pier 98 (P. Baye, unpubl. data 2006). Old patches may decline in vigor because of competition with high salt marsh vegetation, especially high-density overgrowth of pickleweed or iceplant.

Very old intact individuals (probably >10 yr) may exhibit whole-plant senescence marked by accumulation of unproductive woody branches and decline in vegetative and reproductive vigor. Storm erosion events may rejuvenate colonies by reducing competition (scouring away pickleweed, saltgrass) and “pruning” old woody California sea-blite plants with senescent tissues. Moderate to severe mechanical injury caused by storm erosion has been observed to act like pruning, stimulating vigorous vegetative regrowth of new branches on California sea-blite plants. This occurred during recovery of large old plants following storm damage of the west shore of Morro Bay in 1998.

Growth. Seedling growth in Morro Bay appears to be most vigorous (rapid growth, darker green pigmentation/high leaf chlorophyll content) where seedlings are rooted in matted, interbedded eelgrass litter and moist sand. Mature plants in shorelines receiving large wrack deposits of eelgrass litter (e.g. backbarrier Morro Bay sand spit; Figures 9, 10) support more live biomass and leaves with darker pigmentation than plants grown in sheltered shorelines lacking wracks (Figures 4, 6, 8). Decomposition of abundant eelgrass litter in drift-lines likely improves availability of nutrients (especially organic nitrogen) and moisture, as suggested by consistently vigorous growth of sea-blite in eelgrass wracks. Composition of tidal litter in drift-line wracks (litter deposits) varies, and nutrient status of the litter varies with its composition. Litter deposits with high proportions of pickleweed, grass have high C:N ratio, and may act as nitrogen “sinks”; in contrast, and eelgrass and macroalgae litter are relatively nutrient-rich, with high relative nitrogen content (low C:N), and their decomposition acts as a net nitrogen source. Seedling vigor is usually high in drift-lines rich in eelgrass. Individual plants growing in guano deposits beneath the heron/cormorant rookery (Figure 5) are extremely robust and support luxuriant deep blue-green foliage (P. Baye pers. observ.; Figures 9, 10). These observations suggest that like many Amaranthaceae (former Chenopodiaceae) species, California sea-blite is a nitrophile (plant thriving on high levels of soil nitrogen, lacking typical physiological disturbances at extremely high nitrogen levels).

California sea-blite generally grows only in well-drained sandy or other permeable substrates at tidal elevations that reduce submergence to very brief periods. It generally does not establish or grow in fine-grained sediments (silt, clay) that are regularly flooded by seawater. This suggests that California sea-blite has a relatively low level of tolerance to soil waterlogging and hypoxia. Its absence in adjacent stabilized dunes also suggests that it cannot tolerate moisture stress. Moderate levels of burial by sand or wrack (5 – 20 cm), indicated by excavation of partially buried plants after storms, are either tolerated or possibly beneficial to growth.

Population dynamics in shoreline habitats. Seedling colonization of California sea-blite in Morro Bay appears to be opportunistic and intermittent. Seedlings in Morro Bay are generally absent in dense, closed salt marsh vegetation (pickleweed, saltgrass). Seedlings are usually found in open, unvegetated sandy substrates in the high tide line, and in vegetation gaps. Seedlings usually occur within matted wracks of tidal litter, but they also occur on bare sand in the high tide line. The concentration of California sea-blite seeds along the high tide line is due to physical sorting, transport, and deposition of buoyant fruits by wind-waves and currents.

Seedling emergence sometimes occurs in drift-line mats perched over canopies of pickleweed, not in contact with underlying substrate. Seedling emergence on perched wracks over pickleweed occurs during moist periods of rainfall, but perched seedlings, lacking contact with permanently

moist substrate, desiccate and die soon after rains cease. Large numbers of sea-blite seedlings die in perched wracks. Seedlings survive mostly where wracks are deposited either directly on moist sand, or in vegetation gaps where pickleweed and saltgrass have been eroded. Large numbers of seedlings may occur in eroded vegetation gaps along the high tide line following storms. Occasional years of intensive shoreline erosion events may support episodes of increased California sea-blite seedling recruitment by creating vegetation gaps, reducing the proportion of drift-lines that are perched, and dispersing large amounts of seed. Major storm erosion events that trigger seedling colonization are also a cause of mass mortality of juvenile plants and mature populations (P. Baye, unpubl. data 1998-2000).

Physiological ecology. There are no published studies of the physiological ecology of California sea-blite, so field observations of environmental conditions provide the only available species-specific background. Groundwater beneath California sea-blite along high tide shores in Morro Bay, near the upper limits of tidal inundation, tends to be brackish (less than 10 ppt salinity) rather than near marine salinity (34 ppt), owing to leaching by rainfall, groundwater discharge (seeps) from sand dunes and bluffs upslope, or both (P. Baye, unpublished data, 1997-2002). California sea-blite also occurs on well-drained isolated sandy salt marsh berms (natural levees, vegetated sand swash bars) fully exposed to marine salinity, without fresh groundwater influence.

In addition to its halophyte (salt tolerant) physiology, California sea-blite is also a nitrophile, like many other chenopod species: its growth is strongly stimulated by excessive nitrogen. It grows luxuriantly in guano deposits beneath a cormorant/heron rookery, where urea and ammonia levels are toxic to all other vascular plants in the vicinity (P. Baye, unpubl. data, 1997-2001; Fig. 5).

The physical dynamics of Morro Bay shorelines (frequency and intensity of erosion, deposition, stability) appears to be an important factor for the range of California sea-blite habitats. Extreme shoreline erosion causes mortality of seedlings, juveniles, and adults.

1.2. Conservation and recovery efforts

The U.S. Fish and Wildlife Service (Service) has drafted plans to recover California sea-blite in San Francisco Bay by reintroducing founder populations in existing or restored sandy salt marsh habitats, using stock from Morro Bay. Pilot reintroduction projects have been initiated at Crissy Field (Presidio, San Francisco), and Heron's Head Marsh (Pier 98, San Francisco) in the late 1990s, consistent with the recommendations of the San Francisco Bay Area Wetlands Ecosystem Goals Project (Goals Project 1999). The Service is also initiating a program of California sea-blite reintroductions into existing suitable sand and gravel estuarine beaches along central San Francisco Bay shorelines. Restoration and reintroduction of California sea-blite at Pier 94 has previously been evaluated for feasibility, and was recommended in the administrative draft U.S. Fish and Wildlife Service recovery plan for the species (public draft expected 2006). The Pier 94 reintroduction is consistent with current administrative draft recovery plans (Valary Bloom, U.S. Fish and Wildlife Service, Sacramento; pers. comm. 2005), and is expressly recommended in the San Francisco Bay Area Wetlands Habitat Goals Report (Goals Project 1999, p. A-81, recommendation 67).

Two pilot projects have initiated reintroduction of California sea-blite in San Francisco. These pilot projects are useful precedents for the proposed Pier 94 project. Reintroduction of California sea-blite so far has been limited to San Francisco, and nowhere else in San Francisco Bay.

1.2.1. Crissy Field wetland restoration, Presidio, San Francisco. Crissy Field wetland restoration consisted of a reconstructed reduced-scale segment of a barrier beach and lagoon, within the historic area of a filled barrier beach/backbarrier salt marsh complex within the Golden Gate (Presidio Marsh). Its tidal inlet was initially opened in 1998, but it remained subject to intermittent choking by accreted sand and beach ridge growth, causing prolonged periods of non-tidal lagoon conditions. A narrow salt marsh zone fringed the intermittent and tidally choked lagoon. California sea-blite was transplanted along the sandy fringing salt marsh edge in 2000. Transplanted sea-blite plants initially grew vigorously, but were injured by poor drainage and flooding of high water periods during non-tidal lagoon phases. GGNRA has implemented a maintenance regime of artificially opening the unstable tidal inlet soon after it closes, using mechanical excavation, but the original transplants did not recover. A few California sea-blite plants have been transplanted back to the sandy high marsh edge (2004), and is surviving and growing under the improved tidal regime. No spontaneous seedling colonization has been reported from the few plants. (Kristin Ward, GGNRA, pers. comm. 2005).

All San Francisco genotypes of California sea-blite originated with a founder population developed for the Crissy Field project. In 1999, National Park Service (Golden Gate National Recreation Area; GGNRA) in cooperation with U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office, imported clonal stock of California sea-blite from Morro Bay for propagation in GGNRA native plant nurseries. Twenty six genotypes (26 genetically distinct clones) sampled throughout Morro Bay were clonally propagated. The replicate clones matured in the nursery faster than expected, and set abundant viable seed spontaneously in cultivation. The GGNRA nurseries provided propagated clones (and possibly seedlings from cultivated seed) for the Crissy Field wetland restoration, and also the Pier 98 wetland restoration (Heimbinder and Farrell 2000). Plant labels were lost during Presidio propagation and maintenance, and the genetic identity of GGNRA stock and founder populations is no longer available. Replicates of 5 clones were maintained at the U.S. Fish and Wildlife Service San Pablo Bay National Wildlife Refuge headquarters at Mare Island (now moved to Sears Point) until 2002; these also set seed.

1.2.2. Pier 98 (Heron's Head Marsh, Port of San Francisco, Cargo Way). One small population of California sea-blite has recently re-established along the San Francisco shoreline at Pier 98 (next to the Heron's Head Marsh restoration site; Figures 1, 2). Initial introduction of sea-blite to Heron's Head marsh restoration in 2000 largely failed because of unsuitable substrate conditions for transplants. Transplants located in heterogeneous fill containing serpentine soil and rock in the restoration area became chlorotic (deficient in chlorophyll) and moribund (Figure 8). Surviving transplants produced viable seed, however, and seed dispersal resulted in successful spontaneous seedling establishment on a nearby (unrestored) sandy salt marsh formed locally on a small beach ridge composed mostly of shell fragments south of the restoration area (Figure 11; cover). The spontaneous "satellite" Pier 98 colony became a vigorous reproductive population by 2003, forming a heterogeneous high salt marsh vegetation composed of sea-blite, pickleweed, saltgrass, and gumplant (Fig. 2). It has since declined to 4 sea-blite patches (few genetic individuals) because of local sediment supply deficits and competition with pickleweed in the stabilized high marsh vegetation.

The spontaneous establishment of California sea-blite from seed of the transplanted founder population at Pier 98 suggests the feasibility for reintroduction success at Pier 94. The limiting factor for establishment and expansion of the sea-blite population at Pier 98 appeared to be availability of suitable substrate and dynamic beach/marsh edge habitat. Feasibility of reintroduction at Pier 94 may be greater where supply of coarse sediment (sand, fine gravel) and incident wave energy are more favorable for dynamic habitat.

1.2.3. Pier 94 San Francisco, California sea-blite reintroduction

The Port of San Francisco has implemented a habitat enhancement project for intertidal wetland habitats at Pier 94, San Francisco (Tetra Tech 2004). Pier 94 is located near 19th century salt marsh localities of California sea-blite in southeastern San Francisco (Visitacion Bay and a southeast San Francisco shoreline locality; Brandegee 1892). Pier 94 is a derelict urban rubble fill shoreline that has spontaneously regenerated some native salt marsh vegetation. Marsh vegetation has established in part directly on artificial urban port fill (rubble, gravel, sand) and partly on natural bay mud sediments deposited over artificial fill. Some sand and gravel fill has been partially reworked by waves and tides to form small beach ridges at the south and north ends of the site, and at some locations along the landward edge of the high tide line.

In the fall of 2005, the Port of San Francisco implemented a wetland enhancement plan (Tetra Tech 2004) at Pier 94. Primary actions included removal of the largest concrete and asphalt rubble deposits, and recontouring the remaining substrate. Golden Gate Audubon Society (GGA) added a habitat construction and reintroduction project for California sea-blite to Pier 94 by placing 2000 cubic yards of sand (dredged from San Francisco Bay by commercial sand producers) along most of the high tide line in January 2006. This resulted in an extensive ecotone between sandy salt marsh and estuarine beach, open to natural reworking (local erosion, deposition, profile adjustment) by waves.

The first phase of founder population transplanting was implemented in March 2006. It consisted of 20 seedling-grown “mature” plants (grown one full 2005 growing season in cultivation, producing woody shoots) and six cultivated seedlings at the 3 to 4 leaf-pair stage from 2006. The parent population was from Pier 98, itself derived from the Crissy Field founder population. A total of approximately 40 founders will be established by 2007.

1.3. Purpose, Need for Reintroduction of California Sea-blite in San Francisco Bay

There are only two natural historic localities of California sea-blite: San Francisco Bay and Morro Bay. Only the native Morro Bay population survived the 20th century. The unique population at Morro Bay is subject to catastrophic potential disturbances such as oil spills, extreme Pacific storm events, or tsunamis. The risk of species extinction would be reduced by restoring viable populations of California sea-blite in San Francisco Bay. These would have independent risks of mortality and extinction relative to those of Morro Bay. San Francisco Bay is larger, and has diverse shoreline types and exposures that may experience extreme storms, oil spills, or seismic events differently in different parts of the Bay. San Francisco Bay and Morro Bay may also vary in their shoreline responses to accelerated sea-level rise in the next 1 to 2 centuries because of differences in sediment supply, and shoreline engineering responses to sea-level rise. Given the

small population size of this species in Morro Bay, and high level of uncertainty about the effects of potential catastrophic effects on the survival of California sea-blite, restoring a second independent major population in a different estuary within its historic range is a prudent conservation strategy (U.S. Fish and Wildlife Service in prep.).

In San Francisco Bay, the specialized sub-habitat of California sea-blite was probably limited mostly to sand or fine shell fragment deposits along high marsh edges and estuarine beaches, as suggested by its historic distribution in or near locations of historic estuarine beaches. Sand (or shell fragment) beaches and sandy salt marsh habitats are relatively rare in modern San Francisco Bay because of widespread urban shoreline development. Sand and shell beaches have spontaneously regenerated near locations of subtidal and intertidal sand and shell deposits. In few cases, artificial sand beaches have been created and maintained (e.g. Crown Beach, East Bay Regional Parks, Alameda). Some existing potential habitat sites can potentially support persistent reintroduced populations of California sea-blite, depending on landowner agreements and long-term management. Other sites of potential habitat may become feasible to support reintroduced populations of sea-blite if they are restored, enlarged, or enhanced. A suite of major sand and shell beach sites are evaluated in Section 4.0.

The following section establishes habitat goals, objectives, indicators, and criteria for screening candidate reintroduction sites for California sea-blite in San Francisco Bay. Specific sites are evaluated based on habitat indicators, and are ranked according to reintroduction criteria. Site-specific reintroduction plans are proposed for the sites of highest known feasibility and highest potential conservation value. Habitat management and restoration actions, where appropriate, are proposed. Potentially reintroduction sites with higher uncertainty regarding feasibility criteria and long-term conservation value will be addressed with plans for further investigation and conceptual restoration design.

2.0. Restoration and Reintroduction Design: Models and Objectives

2.1. Morro Bay model: habitat goals, objectives, indicators, and criteria.

Very little is known directly about the historic ecology of California sea-blite in San Francisco Bay: most local ecological data on California sea-blite are limited to sparse descriptive information in the older ecological literature and herbarium label information (Table 1). Because native San Francisco Bay populations have been regionally extinct since around 1960, a reintroduction model for California sea-blite must be indirectly inferred from the species' ecology in Morro Bay. The overview of California sea-blite habitat and life-history summarized in Section 1.1, based primarily on observations from Morro Bay, can be interpreted and applied to San Francisco Bay to inform selection criteria for reintroduction sites.

The following descriptive narrative model of habitat structure, dynamics, and population structure is proposed for San Francisco Bay reintroduction of California sea-blite. This model interprets and adapts Morro Bay conditions to correspond to equivalent conditions in San Francisco Bay (equivalent vegetation, species, geomorphic features, processes, etc.). Habitat components of this model are used to propose habitat suitability indicators and criteria. Population components of the model are used to propose reintroduction designs. This account is based primarily on the author's comprehensive annual surveys of Morro Bay shorelines from 1997 to 2002, in support of U.S.

Fish and Wildlife Service recovery plans (P. Baye, unpublished data), and review of the scientific literature.

2.1.1 Morro Bay model: California sea-blite habitat

- **Morro Bay substrates:** fine-medium sand, interbedded sand and eelgrass litter; rip-rap with interstitial sand; oyster shell with interstitial sand.
- **Morro Bay tidal zonation:** drift-line zone (high tide line wrack lines of storm tides associated with highest spring tides and storm surges, fine-textured plant and algal litter) along shorelines exposed to marine salinity tidal waters.
- **Morro Bay shoreline dynamics:** most colonies occur on sandy shorelines with evidence of relict or active wave-cut scarps in high marsh, low sandy bluffs, or low dunes. Presence of vegetation (seedling colonies to mature vegetation) indicates cycles of recovery, stability, or accretion between erosion events. Stable colonies also occur on artificial hard shorelines (rip-rap).
- **Morro Bay seedling colonization habitats of California sea-blite:** California sea-blite seedlings establish in relatively bare vegetation gaps of drift-lines in contact with moist sand, on or bare sand with buried tidal litter. Colonization is typically absent in any undisturbed dense antecedent vegetation (pickleweed, iceplant, saltgrass). Optimal seedling habitat (high survivorship, seedling vigor) is in drift-lines composed primarily of nutrient-rich eelgrass (*Zostera marina*) or other low C:N tidal litter (relatively N-rich detritus, such as marine or estuarine eelgrass, macroalgae) deposited in winter. Seedling growth is inhibited in thick deposits of coarse woody or grassy (high carbon: nitrogen) plant litter, especially if litter mats are perched on pickleweed canopies, not in contact with underlying mineral substrate.
- **Morro Bay vegetation:** frequently associated species in high salt marsh-terrestrial ecotone in contact with California sea-blite: *Sarcocornia pacifica* (perennial pickleweed, also a layering sub-shrub), *Distichlis spicata* (saltgrass), *Jaumea carnosa* (fleshy jaumea, a creeping perennial forb), *Frankenia salina* (alkali-heath, a root-suckering perennial forb), *Atriplex watsonii* (Watson's saltbush, taprooted perennial forb), and *Atriplex triangularis* (syn. *A. prostrata*; spearscale, annual forb)
- **Morro Bay: adjacent habitats lacking sea-blite;** apparent habitat exclusion: regularly flooded salt marsh (below MHHW) with muddy (silt-clay) substrate; high marsh-terrestrial ecotone of brackish tidal marsh and ecotones between fluvial deltas and tidal marsh along sheltered, relatively undisturbed shores; and all terrestrial coastal plant communities
- **Physical indicators:** deposition of sand, shell fragments near high tide line; deposition of fine-textured drift-line wracks (low C:N most favorable); evidence of disturbance patches in variable stages of recovery, or evidence of past disturbance.

- **Observed species indicators:**
Shared Morro Bay/San Francisco Bay species associated with California sea-blite: *Sarcocornia pacifica*, *Distichlis spicata*, *Jaumea carnosa*, *Frankenia salina*, *Atriplex leucophylla*, *Atriplex triangularis*, and *Cakile maritima*. (Equivalent indicator species in San Francisco Bay: *Grindelia stricta* var. *angustifolia*, narrowly associated with well-drained, high salt marsh near spring tide line; *Salsola soda*, (invasive non-native annual species, most vigorous and abundant high tide line wrack deposits; but also a management problem for sea-blite reintroduction; see section 2.2)
- **Counter-indicators:** unvegetated, highly disturbed substrate; deficiency of coarse sediment; closed vegetation deficient in indicators of recent or past disturbance gaps; deposition of massive tidal litter deposits composed predominantly of coarse woody or grassy litter.

2.1.2. Morro Bay model: California sea-blite population structure and dynamics

- **Population size and structure:** Local populations of California sea-blite within Morro Bay vary in size and continuity, but most are linear shoreline colonies, aligned with the narrow high tide zone. The range of colony sizes and distribution patterns include:
 - extensive linear populations hundreds of meters long, composed of hundreds of mature individuals distributed in clusters of tangent plants, with gaps approximately 5 to 10 m apart among clusters (e.g. segments of the backbarrier shoreline of Morro Bay sand spit);
 - colonies of 10-60 mature individuals distributed in clusters with gaps approximately 1-10 m between clusters (e.g. Museum Beach at Fairbank Point; Marina; Baywood Park shoreline; Table 4); and
 - isolated, loose, small colonies (fewer than 5 individuals) of widely spaced individuals (most over approximately 10 m apart), relatively isolated from alongshore drift vectors of seed dispersal from larger colonies; e.g. Morro Harbor entrance, south shore; Morro Bay State Park campground marsh; Pickleweed Island), (Table 3)

Seedling colonization pattern and process: Seedling colonies occur in patches associated with (a) erosional disturbance gaps in high salt marsh vegetation; or (b) drift-line deposition on unvegetated estuarine sand beaches. Seedling colonization is episodic, related to winter storms (erosion, drift-line deposition) and spring rainfall patterns. Mortality risks for seedlings are generally high. After one growing season in favorable sites, surviving juvenile plants grow quickly and gain size (taproot, trunk, and basal branch mass) sufficient to reduce risk of mortality to low levels.

Seedling mortality is highest if sand or litter desiccates in the seedling root zone in spring, before seedling taproots have elongated through drift-line detritus deep enough into underlying moist sand to exploit horizons of permanent moisture. Seedling mortality

is also high on unstable sand shorelines subject to rapid erosion or burial of small seedlings.

- **Mature population structure.** The seedling colonization model suggests that a local mature (reproductive) California sea-blite population would be derived from former disturbance patches with cohorts of seedlings, recruited in the same season following drift-line deposition events. Resulting mature colonies derived from surviving seedlings would consist of patches of closely-spaced individuals (nearest neighbors less than 1 m to several meters) in roughly linear distribution along the high tide line, in association with drift-line wrack deposits of winter storms. This population structure would result in local “breeding neighborhoods” of cross-pollinating individuals.
- **Patch dynamics and juvenile/mature population pattern.** Sites of established, mature reproductive colonies would form closed vegetation over time, and would be negatively associated with seedling recruitment. Mature colonies would instead function as parent seed source patches. Parent seed source patches would interact with storm disturbance gaps in high tide vegetation in the vicinity of seed parents, where seeds would be dispersed in drift-lines and seedlings would be recruited. Seedling recruitment and survival would be episodic or cyclic, based on storm disturbances (or initial early succession conditions with high proportions of uncolonized habitat) and annual rainfall patterns.
- **Storm disturbance and post-storm vegetative recovery cycle.** Major storm erosion events remove significant amounts of mature sea-blite biomass, severely “pruning” old individuals, or partially exposing their taproots through substrate erosion. Plants with root systems mostly exposed by erosion are at high risk of mortality (particularly on steep shorelines, where erosion is likely to expose and undermine taproots). Storm-damaged (naturally pruned) mature individuals, with taproots only superficially exposed by erosion, usually regenerate vegetatively, and they may regain vigor and resume abundant seed production after one year. Severely storm-damaged old plants, and plants in competition with dense terrestrial or high marsh vegetation, are at high risk of mortality.

2.2. Adapting the Morro Bay model to San Francisco Bay

The Morro Bay model of California sea-blite population structure and dynamics would generally apply to San Francisco Bay, but with some modifications based on spatial and geographic differences. Most of Morro Bay supports potentially suitable sandy high tide habitat for the species, and there are no major breaks in shoreline continuity that would cause major barriers to dispersal. In San Francisco Bay, suitable habitats are relatively small and widely separated by unsuitable habitats and tidal re-entrants (embayments) that would be likely to act as barriers to dispersal (seed deposition traps). With some exceptions, the chance of metapopulation structure developing between independent reintroduction sites in San Francisco Bay (significant immigration, gene flow among populations) is small. In contrast, local population extinctions of California sea-blite in Morro Bay may be subject to relatively frequent recolonization from long-distance dispersal among discrete colonies within the bay. This geographic pattern of distribution of estuarine beach habitats in early historic San Francisco Bay may have been a factor in the natural rarity, and eventual regional extinction, of California sea-blite. Thus, the Morro Bay

model would apply primarily at a local scale in San Francisco Bay, and would be most applicable to larger reintroduction sites.

San Francisco Bay has relatively fewer and more localized eelgrass beds than Morro Bay, and tidal litter sources are usually dominated by grasses, bulrushes, and tules (coarse, high C:N tidal litter). Some shorelines have locally high tidal litter inputs of membranous or filamentous marine algae (*Enteromorpha*, *Ulva* spp.) and eelgrass. San Francisco Bay also has relatively higher wave energy than Morro Bay because of greater fetch and depth that allow breaking wave heights in excess of 60 cm along some sandy shores during high wind events (P. Baye, pers. observ.)

2.2.1 General qualitative model of suitable San Francisco Bay habitat: Estuarine beaches composed of sand or shell fragments, subject to cyclic erosion and accretion, vegetation gaps, and periods of colonization by perennial high marsh and beach vegetation. Persistently unvegetated beaches would indicate excessive wave energy, erosion rates, or sediment mobility. Dense, complete high marsh vegetation cover persisting for many years would indicate relatively low suitability. Presence of unstable disturbance gaps, patchy perennial vegetation, and moderate deposition of tidal litter (wracks) would be positive indicators of habitat suitability. Abundance eelgrass or macroalgae (low C:N ratio *Enteromorpha*, *Fucus*, etc.) organic matter in high tide wracks would further enhance habitat suitability. Fresh to brackish water table tables near mean sea level, typical of estuarine beaches, are also favorable.

2.2.2 General qualitative model of reintroduced San Francisco Bay population dynamics

The following general predictions describe the expected results of California sea-blite reintroduction in San Francisco Bay. Key life-history features and expected ecological processes or events are highlighted.

- **Seed reproduction in the founder population.** Closely spaced founders (cross-pollinating breeding neighborhoods) would produce abundant seed within local colonies beginning the second growing season after transplanting. Some larger transplanted individuals may reproduce the first growing season after transplanting. Seed output would increase with plant size. After 3 to 5 years, founder colonies would approach maximum size and seed production in periods of moderate storm energy.
- **Patchy seedling recruitment in vegetation gaps.** Most seed would be locally dispersed in high-tide drift-lines. Seedlings would establish primarily in vegetation gaps and relatively bare substrates (sand, sand-buried drift-lines, drift-line tidal litter) where seeds are deposited at high density. Seedling recruitment would vary with seed production, dispersal (storm) events, and availability of seedling microhabitats in drift-lines. Seedling abundance would diminish with occupation of high tide line space by competing species (particularly non-native *Salsola soda*, *Distichlis spicata*, *Sarcocornia pacifica*, *Grindelia stricta*). Seedling recruitment is likely to fail in areas of chronic erosion or excessively high disturbance.
- **Cyclic, episodic seedling recruitment.** Seedling recruitment is likely to occur in cycles or pulses (flushes) following winter storm events that deposit drift-lines, seed, and erode

vegetation gaps. Seedling recruitment would be unlikely when the high tide line is well-vegetated and undisturbed between storm erosion events.

- **Seedling recruitment and wrack composition.** Deposition of thick, dense tidal litter wracks may be detrimental to seedling establishment. Wracks composed primarily of coarse woody debris or dense mats of *Spartina alterniflora* hybrid litter (recalcitrant, very high C:N, poor moisture retention, coarse texture) would probably significantly reduce successful recruitment of California sea-blite seedlings.
- **Climate variability and seedling mortality.** High mortality of naturally recruited seedlings would typically occur in dry springs (early cessation of rain) or spring-summer periods with exceptionally high storm tides. High survivorship of seedlings would be likely in years of late, well-distributed rainfall after pulses of seedling recruitment.
- **Interference by high tide line vegetation.** Significant seedling competition may occur with non-native Mediterranean saltwort, an annual with similar patterns of dispersal and environmental tolerances (concentrated abundant seeds and seedlings in tidal litter of drift-lines; salt-tolerant, and fast-growing relative to sea-blite). Prolonged periods of shoreline stability may favor competition by dominant high salt marsh plants or adjacent terrestrial vegetation.
- **Second generation reproduction.** Plants established as seedlings that survive to reproductive maturity would usually begin flowering and seed production in the second growing season after establishment. Time to flowering is size-dependent: vigorous plants may begin reproduction as soon as the end of the first growing season in favorable conditions.

2.3. San Francisco Bay reintroduction: goals and objectives

2.3.1. Reintroduction Goals based on the conceptual model. The principal goal for establishment of a founder population is *to generate a local, self-maintaining seed source for local dispersal and colonization of suitable high tide line (drift-line) habitat*. The long-term growth and survival of transplants themselves are not the primary aim of reintroduction: the long-term goal is to recruit multiple generations of sea-blite established spontaneously from seed. The primary purpose of the founder population is to provide an ongoing local seed source for colonization. The survival and growth of the planted founder population will be essential to the reintroduction until a second (spontaneous seedling-grown) generation is established, and achieves a minimum self-sustaining population size. It is likely that the founder and second generation sea-blite populations will persist and co-exist for many years. Goals and objectives for the habitat restoration and reintroduction of California sea-blite are summarized in Table 3, and discussed in detail below.

2.3.1. Reintroduction objectives based on the conceptual model. Specific population objectives for minimum self-sustaining reintroduced populations of California sea-blite must be adapted to site-specific conditions. Available shoreline length (space available) is a critical factor to estimate a maximum mature population size. The degree of shoreline exposure to wave

attack, intensity of erosion events, and frequency of erosion/recovery cycles, are also important factors for estimating population turnover and setting objectives for seedling colonization.

- **Population size objectives.** A theoretical maximum population size would consist of a “saturated” shoreline of closely spaced transplants (nearest neighbor distances less than the mature maximum width of mature plants, approximately 2 meters) that occupy all available high tide line. “Saturation planting” (full occupancy of available suitable habitat by transplants) of the high tide line would maximize population size, cover, and seed production of the reintroduced population, but it would also maximize its artificiality. This would be counterproductive for overall reintroduction goals because this population structure would maximize artificial founder effects of the (artificially propagated) transplant population, and minimize potential for seedling recruitment. Because it is desirable to minimize the proportion of artificially transplanted long-lived founders in the population, the number of founders should not approach the upper limits of estimated natural density in a patchy population.

A more appropriate founder population size objective, based on an adapted Morro Bay model of local California sea-blite colonies, would be patterned on discontinuous mature sea-blite patches covering about 10% to 50% of the occupied high tide sand shoreline, leaving available space for seedling colonization in gaps between occupied mature patches. Initial founder (transplant) population sizes between 10 to 30 plants would approximate the range of natural local mature population sizes of small, discrete mature colonies of California sea-blite observed in Morro Bay (Table 4). A local founder population size around 30 to 40 also satisfies the default recommendation of genetic sampling of 10 to 50 individuals per source population (Center for Plant Conservation 1992). A patchy founder population structure would also be more conducive to spontaneous recruitment of seedlings, a primary goal for reintroduction.

Founder populations of fewer than 20 plants in an isolated population (no immigration) may increase the risk of inbreeding depression, loss of desirable genetic diversity to allow natural selection to occur, or neighboring incompatible mating types.

The effective population sizes (theoretical random mating population, lacking pollination neighborhood effects) would be considerably smaller if the population is distributed in local patches with minimal gene flow (pollen, seedlings) between patches. Estimation of effective population size is not feasible because data on gene flow in California sea-blite have not been studied.

The proposed population size objective for reintroduction sites is a *minimum breeding population size of 20 individuals over at least a 5 year period*. The *reproductive objective* for the minimum breeding population may be met by a combination of surviving transplants and naturally recruited plants *that mature and produce abundant seed annually*. An *initial local founder population of 30 to 40 plants* would be a “conservative” (local extinction risk-averse) to high initial size relative to most Morro Bay colonies, and is recommended for larger reintroduction sites with sufficient available space.

To spread the risk of catastrophic (storm, drought, etc.) mortality, founder populations may be phased (planted over two or more seasons), distributed over reintroduction sites. Mature, productive plants should produce at least several hundred viable seed annually, and are likely to produce many thousands of seed, based on observations of vigorous plants at Pier 98, Presidio Nursery, and wild populations of Morro Bay.

- **Seedling recruitment objectives.** Seedling recruitment objectives would be difficult to quantify among years and spatially, because seedling dynamics are naturally highly variable: they are subject to storm disturbance cycles, and include many complex, unpredictable environmental influences.

A general qualitative objective for seedling recruitment is *to detect multiple patches of seedlings on the site during the growing season following significant storm events that generate disturbances* (erosion of high tide line vegetation and sand, redeposition of drift-lines and sand). This qualitative objective could be met after the founder population matures and produces abundant seed. This may occur as soon as 2 years after initial plantings. In addition, at least one seedling cohort (seedling generation of relatively uniform age) within five (5) years should contribute enough surviving individuals to cause net population increase at the site. Failure to detect surviving seedlings that mature into reproductive individuals within 5 years would indicate that the reintroduction is not yet achieving dynamic population objectives.

- **Long-term population objectives.** The final test of reintroduction success is to *recruit a second generation of seedlings after the first seedling cohort reaches reproductive maturity and produces mature, viable seed*. This would demonstrate that the population is able to complete its life-cycle in dynamic natural habitat conditions. This would also be a qualitative objective, because there is no natural San Francisco Bay reference population to compare “natural” levels of multi-generation reproduction. The overall population criterion should be *net breeding population growth* (net increase in mature, reproductive individuals) *at the time of the second generation of seedling recruitment*. Because seedling mortality is subject to unstable fluctuations, measurement of population growth trends should be based on mature (flowering or seed-bearing) individuals.

3.0 San Francisco Bay reintroduction: methods and designs

3.1. Propagation of founder populations

The founder populations would necessarily be artificially transplanted rather than seeded because of excessive risk of mortality in the seed germination and seedling life-history stages of perennial and woody plants (Guerrant 1996), and because of very limited seed supply of California sea-blite in San Francisco Bay.

Seed and population sources

The California sea-blite seed source currently available in San Francisco Bay originated with the Crissy Field founder population. This cultivated founder population originally comprised 26 clones sampled from multiple sub-populations representing all of Morro Bay between 1997 and

1999. The Crissy Field population is reduced to 2 individuals in 2006 because of non-tidal submergence of the lagoon. The primary seed source available in San Francisco Bay in 2006 is the local Heron's Head population, which consisted of at least 3 robust seed-producing patches (possibly more than one genotype per patch) in 2005, and over 5 patches in 2003. Additional limited supplies of stored seed sampled from 5 replicate clones of the Crissy Field founder population, grown at Mare Island in 2001 and 2002, are currently in propagation.

Seeds of California sea-blite were sampled from all seed-bearing plants at the shell hash beach ridge south of Heron's Head Marsh in 2003 and 2005, in support of the Pier 94 (Golden Gate Audubon) reintroduction and potential additional reintroductions through the U.S. Fish and Wildlife Service. Additional surviving but depauperate old transplants at Heron's Head that produced few or no seed may have provided some pollen for the seed-bearing plants sampled. One cohort of 49 seedlings from bulk seed combining Mare Island and Heron's Head sources was propagated in spring through fall 2005, in coordination with the U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office, Recovery Branch (Valary Bloom). Plants were grown in irrigated and bottom-watered 4 inch containers in outdoor tubs, with sand-compost medium (see seedling propagation, below). Plants were acclimated in a maritime location on the San Francisco peninsula in winter 2006. Moderate frost injury affected plants in January 2006, but plants vegetatively regenerated from buds within weeks. An additional cohort of approximately eighty (80) seedlings for a regional reintroduction program was propagated in winter 2006.

Seedling propagation.

To avoid high mortality risk associated with small first year seedlings, established (1 growing season) propagated plants would be transplanted as founders. Direct seeding is not proposed because of insufficient seed sources, high effort and cost of growing large numbers of seed in cultivation, and low expected seedling survivorship (high uncertainty, low % survival).

Ripe (black, hard-coated) seed are collected from summer to late fall when available from San Francisco Bay source populations (currently limited to Herons Head Marsh, San Francisco). Harvested or stored seed can be germinated with minimal moist-chilling (5°C for two to three weeks) pre-treatment, or seeds can be sown in fine sand medium in outdoor flats in winter for spring germination in a frost-free or minimal frost maritime climate setting. Day temperatures over 15°C to 25°C stimulate germination. Seedlings should be exposed to full sun, and exposed to cool night temperatures. Seedlings developing the second pair of true leaves should be transplanted to minimum 15 cm diameter containers and grown in a fine sand/compost (50:50) medium. Rapid growth of seedlings is stimulated by high nitrogen fertilizer, which is not harmful to this species. Dilute, gradual salinization of irrigation water (5 ppt) within 4 weeks of outplanting is beneficial for acclimation to field conditions, resistance to transplant shock, and for resistance to potential moisture stress or frost injury after transplanting. Growing medium should be constantly moist but not saturated (waterlogged). Roots can be allowed to grow through containers drainage holes into a "buffer" medium to minimize risk of wilt/drought injury. To prevent imbalance between root:shoot ratio ("pot-bound" plants, excessive moisture stress), plants in propagation may be partially shoot-pruned, potted up to 15 cm diameter containers, or both.

Cutting propagation. Clonal propagation of known genetic individuals from established plantings (Piers 94, 98, and Crissy Field, San Francisco) may be used to supplement the diversity of genotypes in new founder populations. Axillary vegetative shoots should be selected from near the base of the parent plant, excised at or below the junction with the main stem (“heel” cutting including the lowest internodes of the axillary shoot), and treated with a commercial liquid rooting hormone (synthetic auxin) dissolved in isopropyl or ethyl alcohol at rates recommended for softwood cuttings. “Heel” cuttings contain short basal internodes, near the point of attachment to the main shoot; these short basal internodes are morphologically predisposed to form root primordia. Retaining the small woody “heel” of the main shoot at the base of the cutting helps it resist infection by pathogenic fungi. Optimal timing of cuttings is in spring when lateral vegetative shoots are less than 6 cm long. All leaves except those at the top 1 cm of the cutting should be removed. Cuttings should be placed in a medium composed of fine vermiculite and peat moss (50:50), and grown either directly beneath cool white fluorescent lamps or bright-diffuse, filtered sunlight (30% to 50% shade) under a loosely ventilated clear plastic tent. Temperatures for rooting should be similar to those for seed germination. Cuttings should root within 2-4 weeks. Rooted cuttings should be grown as for seedlings.

3.2 Transplanting in reintroduction sites (outplanting)

3.2.1. Timing of transplanting

Seasonal transplanting time factors. Seasonal timing of transplanting for optimal growth and survivorship is set by a balance between two opposing environmental influences: (a) coinciding transplanting with ample rainfall, conducive to low soil salinity and high soil moisture for extensive root growth; and (b) avoidance of storm wave erosion that can excavate and uproot plants. Maximum root development, sufficient to support growth and survivorship during the long rainless summer growing season and salinity pulses of summer solstice high tides, requires transplanting during the variable rainfall season of the Central California coast. Transplanting during warm, sunny, or dry weather in spring, before root systems have expanded to exploit large volumes of moist sand, is likely to result in severe moisture stress in summer.

The solstice high tides and early winter high tides (late December/early January, late January/early February) are likely to coincide with Pacific storms, and carry a relatively high risk for erosion and mortality of transplants in the high tide line. Planting in early winter, therefore, should occur only in highly sheltered shoreline positions, or in conditions where erosion risk is minimized by temporary or persistent surface stabilization (e.g. placement of rock, shoreline locations with armored or cohesive substrates). At exposed, high energy shoreline sites, transplanting should be delayed until storm patterns have subsided and winter solstice high tides have past.

The annually adjusted seasonal planting period can vary with annual climate fluctuations. In years with high winter storm frequency and intensity, and relatively late spring rains, transplanting may be delayed until neap tides of spring (March). In years with low storm frequency and intensity, and relatively dry winter weather (infrequent rainfall), transplanting may be scheduled as early as mid-January to early February. Planting in January or early February, when storms and high astronomic tides may pose erosion risks, may be mitigated by (a) selection of planting locations with maximum shelter, and rejection of more exposed transplant sites; (b) temporary placement

of rock or rubble armor around transplants to reduce surface erosion. Temporary rock/rubble placement cannot mitigate risks of beach scarp (vertical cliff retreat) erosion and undermining.

Annual planting schedule. Transplanting of founder populations can, and usually should, be phased among years to spread the risk of catastrophic transplanting failure due to extreme winter storm erosion events, unusually stressful summer climate conditions, vandalism, or other high stakes/low frequency sources of mass mortality. Spreading founder transplanting among 2 years is generally prudent, and 3 year phased transplanting may be indicated if first-year catastrophic disturbances occur.

3.2.2. Spatial pattern of transplanting

Transplants should be dispersed in clusters of at least 3 neighbors spaced 1 to 2 m apart, within 1 m of the approximate center of the high tide line (delineated by tidal litter drift-lines of higher winter tides). Clustered plantings ensure proximity of cross-pollinating neighbors, minimizing pollen limitation risks. Dispersing plants at least 1 m apart ensures that significant above-ground competition among transplants would be unlikely to occur for at least two growing seasons, by which time transplants should be well-established, and unlikely to suffer significant mortality risks due to competition.

Transplants placed at elevations below the higher drift-lines may suffer higher risks of root excavation by erosion in wave-exposed shorelines. Transplants may be located at the lower end of a series of upper drift-lines in highly sheltered or stable shorelines. Transplants placed on the flat tops of swash bars (beach ridge crests) on transgressive shorelines (beach retreat, onshore migration) should be located towards the landward edge of the beach ridge at elevations close to the high tide line.

Transplant microsite locations: The best plant indicators of suitable shoreline positions include sea-rocket (*Cakile maritima*), Mediterranean saltwort (*Salsola soda*; Fig. 12), gumplant (*Grindelia stricta* var. *angustifolia*; Fig. 12) and beach or whiteleaf saltbush (*Atriplex leucophylla*; Figure 12) associated directly with drift-lines. Pickleweed (*Sarcocornia pacifica*), alkali-heath (*Frankenia salina*), saltgrass (*Distichlis spicata*), and beach-bur or beach-bur/ragweed intermediates (*Ambrosia chamissonis*, *A. chamissonis* x *psilostachya*; Figure 12) associated with San Francisco Bay drift-lines may also indicate suitable shoreline positions, but these species have wide ecological amplitude, and should only be used as planting guides when they are clearly associated with tidal litter deposits and at least one primary plant indicator. Spearscale (*Atriplex prostrata*; syn. *A. triangularis*; Figure 12) associated with drift-lines at high density is also a good indicator of high tide line habitats suitable for sea-blite.

The extent of vegetation cover is an important indicator of transplant microsite suitability. Drift-lines or beaches entirely lacking established perennial vegetation along their entire length are usually indicators of excessive recent erosion, and should be presumed to be unsuitable risks for transplant sites. Sites supporting only annual plants (*Salsola*, *Cakile*) and seedlings of perennial plants should be presumed to be at high risk of catastrophic erosion for sea-blite transplants. Sites with dense cover of *Distichlis* or *Sarcocornia* (especially below-ground biomass) are also indicators of poor transplant sites, owing to root competition with young transplants. Sand beaches with scattered patches of perennial forbs or subshrubs, or sandy high salt marsh

perennial/subshrub vegetation with scattered bare patches (at least several meters in area), are most likely to be suitable transplant sites. Exceptions may include barren or annual-dominated sites with artificial rock slope protection (stabilizing underlying substrate in otherwise high-energy, erosion-prone settings).

3.2.3. Transplanting technique.

Transplants should be set with the container growing medium surface set at least 10 cm below (up to 20 cm) the surrounding sand surface, burying the base of the plant. At least 20 cm of leafy shoot growth should be exposed above the sand surface. The surface of the root ball (growing medium with roots) should be roughened to loosen root tips growing along the container inner surface, and cause minor root breakage and branching. The planting hole (manually dug pit) should be over-excavated to a depth of approximately 40 cm, and a diameter of 30 to 40 cm. A mixture of sand and local seaweed (macroalgae) or commercial steer manure should fill the bottom 15 cm of the planting hole. Larger planting holes with larger amounts of organic matter should be applied to sites with low inputs of suitable tidal litter. The backfill should be tamped firmly (recompacted) and wetted with fresh water or dilute high-nitrogen commercial fertilizer solution (about ½ strength recommended for horticultural use). At least two patches of sand/macroalgae or sand/composted manure should flank the transplant. The transplant hole should be completely backfilled with moist sand, and tamped firmly to compact the sand, eliminating air pockets and ensuring contact between root tips and moist sand. The transplant should be watered with fresh water to temporarily saturate the backfilled pit. The surface of the sand should be mulched with about 5 cm of organic debris free from Mediterranean saltwort (*Salsola*) and sea-rocket (*Cakile*) seed.

3.2.4. Transplant marking and labeling.

Each transplant should be marked with a permanent aluminum tag wired to the base of the main shoot near but below the sand surface. The position of the tag should be marked above ground with an inconspicuous but retrievable stick or flag. The transplant code (date of planting/cohort, number) should be clearly embossed on the tag for monitoring purposes (4.0). Marking founders is important for distinguishing transplanted and naturally recruited individual clones after many years.

3.2.5. Adaptive post-transplant management (first growing season).

Several predictable adverse influences may affect recent transplants in San Francisco Bay. Primary threats are:

- Competition with Mediterranean saltwort (*Salsola soda*; Fig. 11 a);
- Competition with iceplant (*Carpobrotus edulis*) extending from adjacent terrestrial vegetation;
- Excessive shoreline erosion and lack of perennial vegetation establishment;
- Moisture stress, or sand desiccation within limited seedling rooting zones;
- Soil hypersalinity following high tide flooding when root systems are immature;
- Trampling injury;
- Nutrient limitation/nutrient deficiency

Competition with rapidly spreading saltwort or iceplant should be mitigated by periodically clearing transplant areas manually in spring and early summer. Iceplant should be removed (including roots) at least 6 feet away from transplants.

Shoreline erosion damage should be avoided by selection of suitable planting locations; high erosion rates should be presumed to be inherent with the position, and should not be mitigated. Replanting at more sheltered or higher locations should follow erosion-related mortality.

In years of late spring rainfall, summer moisture stress may not be a significant constraint, but growth and survivorship are likely to improve with localized manual addition of freshwater (single episodes of flooding within a circular berm around the planting hole boundary, to temporary saturation) if it is practical during the first growing season. No watering should occur after the first growing season. Transplants exhibiting low turgor (partial wilt) should be watered with fresh water if possible.

Temporary hypersalinity stress may also be mitigated by flushing sand around the root zone with nonsaline water, followed by dilute fertilizer solution. Adequate nitrogen nutrition in Chenopodiaceae (goosefoot/spinach family species) improves physiological salt-tolerance by supporting synthesis of compatible osmotic solutes containing nitrogen compounds. Chronic hypersalinity stress cannot be mitigated, and should be presumed to indicate an unsuitable planting position.

Trampling injury may sometimes be prevented by flagging or temporary fencing in areas that are subject to low vandalism pressures. If vandalism risk is high, sheltering the transplants plants by surrounding them with natural-looking accumulations of woody debris on the sand surface may reduce the risk of casual trampling, while disguising the deliberate planting position.

Most modern San Francisco Bay shorelines are deficient in nutrient-rich eelgrass tidal litter and macroalgal tidal litter; they are instead dominated by poorly decomposed grassy tidal litter (tule, cordgrass, bulrush) or coarse woody debris with high carbon:nitrogen ratios that act as a microbial nitrogen sink, robbing available soil nitrogen from vascular plants (Figure 13). Mulching transplants with harvested local macroalgae (seaweed) semi-annually may ameliorate nutrient stress if competition with other high marsh vegetation is moderate. Mulching with salt-rich macroalgae should be done only in winter and early spring during rainy weather patterns. Fertilizer addition may also cause problems with plant competition, so nutrient addition (organic or otherwise) should be limited to transplants with little or no vascular plant competition. Fertilizer application may benefit isolated plants free from competition. Soluble salt fertilizers are not retained in sandy substrates, and are not recommended.

4.0. Reintroduction site selection in San Francisco Bay

The historic distribution of sand and shell beaches in San Francisco Bay was reviewed by examination of U.S. Coast Survey T-sheets of San Francisco Bay, which mapped detailed landforms and coarse sediment foreshores. This source also serves as the primary data layer for the San Francisco Estuary Institute's EcoAtlas (www.sfei.org) map of historic estuarine beaches in San Francisco Bay. Historic San Francisco Bay localities of California sea-blite were obtained

by review of herbarium records (www.calflora.org; manual examination of California Academy of Sciences/Dudley Herbarium collection) and published historic floras (Table 1). Recent aerial photographs and satellite imagery were examined to locate significant emergent (supratidal) deposits of sand and shell from Point Pinole (vicinity of “San Pablo Landing”, historic northern limit of California sea-blite) to the Ravenswood marshes (historic southern limit). Locations accessible by foot were assessed through reconnaissance surveys in 2002 to 2006. Potential reintroduction sites with physical and ecological indicators of most suitable existing habitat for California sea-blite were re-surveyed in fall 2002 and late winter 2006. These most feasible sites were advanced for site-specific reintroduction plans. Potential reintroduction sites that would require physical modification (significant restoration, enhancement, coastal engineering, or extensive permitting and coordination) were deferred to future planning. Sites with inherent long-term obstacles to feasible reintroduction were eliminated from further review unless conditions change (details discussed below). The three ranks in which sites were classified are:

Tier 1 sites: Highly feasible existing habitat (proposed reintroduction sites)

Tier 2 sites: Potentially feasible habitats with modification or experimentation

Tier 3 sites: Low feasibility habitats.

The overall distribution of candidate sites is shown for the region in Map 1, and in greater detail for the Central Bay in Map 2.

4.1. TIER 1 SITES

4.1.1. Radio Point Beach and marsh complex, Oakland, Alameda County (Figures 14-19)

Location: Oakland, Alameda County, at north end of Grand Avenue, north side of Oakland Bay Bridge approach; landmark: radio towers.

Property ownership/management: Multiple ownership. Radio Point Beach (west-facing beach): Eastshore State Park (East Bay Regional Parks District). Unnamed north-facing sand spit east of radio tower: (unverified; Port of Oakland). North-facing estuarine beach and high salt marsh fringing Emeryville Crescent tidal flats: mixed ownership: west, unverified Port of Oakland; east, East Bay Regional Parks. No active management.

Prevailing land uses: low-level local recreational use, mostly recreational fishing; wildlife habitat, passive management. Highly localized trampling patterns indicate grandfathered local fishing spots.

Public access: Parking along frontage road at end of Grand Avenue (exit at westbound Bay Bridge approach or Grand Avenue south of Bay Bridge, Oakland). Pedestrian access. No signage. The marsh is enclosed by degenerated fencing that is breached and routinely crossed near fishing spots.

Existing habitat and vegetation: sand beach, drift-line annual beach vegetation, non-native foredune vegetation on Radio Point Beach (iceplant, *Carpobrotus edulis*; pampas grass,

Cortaderia selloana); tidal and non-tidal salt marsh (dominated by pickleweed, hybrid smooth cordgrass), estuarine beach with high salt marsh ecotone facing Emeryville Crescent flats.

Site description:

Physical setting: Radio Point Beach is a modern barrier bay beach and marsh complex formed around an artificial headland (access road, radio tower foundation) (Figure 14) Radio Point Beach is formed by wave deposition of reworked Merritt sand (quartz-rich, well-sorted Pleistocene beach and dune sand deposits). It faces west, exposed to high waves and long wave and wind fetch towards the Golden Gate. The beach is deposited in front of a degenerated access road to the radio tower. A low (1.5 m), narrow (less than 5 m) foredune ridge has formed in back of the beach. It supported multiple northwest-oriented blowouts in the early 1990s, but now consists of a persistent linear wave-cut scarp approximately 1 m high. The beach is relatively steep, sloping seaward from the toe of the foredune scarp, suggesting a chronic erosional profile. Annual beach vegetation is confined to the extreme south end, where the beach is somewhat sheltered from direct westerly wave attack.

A small non-tidal salt marsh (infrequently flooded by extreme high tides overtopping the road) occurs between the beach and the tower access road (Figure 14). A larger tidal salt marsh with a natural tidal creek system has developed in the lee of the barrier beach and road. The northwest end of the tidal marsh occurs in the lee of a smaller, irregular sand spit (Figures 14, 18) The eastern tidal creek and marsh system has become encroached by hybrid smooth cordgrass. Smaller pocket beaches, transitional to high salt marsh, occur along the north-facing shore (Figs). Further east, the salt marsh is reduced to a narrow fringe with a wave-deposited natural low levee (sand and coarse debris) supporting high salt marsh vegetation.

Habitat and vegetation: Radio Point Beach has drift-lines composed of eelgrass and macroalgae (mostly filamentous and membranous marine algae), likely derived from nearshore eelgrass beds and sandy flats. High tide drift-lines are dominated by dense, tall, robust stands of *Salsola soda* and *Atriplex triangularis*, but little *Cakile maritima*. The foredunes are dominated almost entirely by *Carpobrotus edulis* in areas of active sand deposition, and *Cortaderia selloana* in stabilized rear edges of the foredune (Figures 15, 16). Some *Ambrosia chamissonis* occurs in the foredune. The sand spit east of the radio towers is mostly unvegetated, with scattered colonies of *Atriplex triangularis* and *Salsola soda*, and mature clumps of *Grindelia stricta* var. *angustifolia* on the landward portions and relict, semi-stable beach scarps (Figure 18). The tidal salt marsh supports a relatively diverse assemblage of *Sarcocornia pacifica*, *Jaumea carnosa*, *Distichlis spicata*, *Spergularia macrotheca*, *Frankenia salina*, local strips of *Grindelia stricta*, and large recently established stands of *Spartina alterniflora* x *foliosa*. Pocket beaches along the eastern salt marsh segments support ecotones of open sand with algal drift-lines, cordgrass litter, *Distichlis-Sarcocornia-Grindelia* high marsh grading into *Carpobrotus edulis*, *Ambrosia chamissonis*, annual grasses, and infrequent *Atriplex leucophylla*. Further east, natural wave-constructed high marsh levees support mostly closed vegetation of *Grindelia*, *Sarcocornia*, and *Distichlis*.

Evaluation: Radio Point Beach itself currently has limited potential to support transplanted founder plants of California sea-blite because the beach and foredune scarp profile is too steep and chronically erosional, retreating too quickly to support a beach ridge (berm) with sufficient stable area for perennial forbs. It may become suitable habitat for sea-blite reintroduction with

sand nourishment. The presence of abundant eelgrass and macroalgae in drift-lines is an important positive habitat indicator, but its potential habitat benefits cannot be realized without suitable beach structure and dynamics.

In contrast, the sand spit east of the radio towers, and the pocket beaches fringing the north-facing salt marsh near Grand Avenue, support suitable habitat for transplanted founders (and subsequent natural seedling recruitment) of California sea-blite. The presence of *Atriplex leucophylla* (a perennial sand-dependent, moderately salt-tolerant forb with similar ecological requirements) is a strong positive indicator of suitable habitat. The sand spit has a berm profile with enough annual beach vegetation and sparse perennial *Grindelia* to indicate suitable transplant and seedling recruitment habitat for sea-blite. The landward portions of the sand spit would probably be sufficiently stable to support founder plants, and the eastern end tied to the artificial headland fill would also likely be stable enough for transplants. The long-term viability of sea-blite habitat would depend on eradication of hybrid smooth cordgrass, which is progressively eliminating foreshores with unimpeded sand transport and wave energy. The long-term viability of sea-blite habitat on the spit and pocket beaches facing Emeryville Crescent tidal flats would be enhanced by sand nourishment of the sand spit and foreshore following eradication of hybrid smooth cordgrass.

Site-specific reintroduction: Transplants of California sea-blite should be distributed in small colonies (clustered plantings) at two locations: (1) along the proximal (west) end of the sand spit and landward portions of the spit, near *Grindelia*, in open sand at or slightly above the high tide line; and (2) in at least two pocket sand beaches (transitional to high salt marsh) at the east end, near the end of Grand Avenue. Transplants should be spaced so that mature size plants are not likely to capture all available open sand space (conserving some seedling habitat). Two to three colonies (3 to 5 plants each) should be distributed on the sand spit, and up to two colonies may fit in existing pocket beaches. Transplanting methods are described in Section 3.2.

Future potential management actions: *Salsola soda* may need to be removed in a minimum 2 m wide area around transplants for the first two years of California sea-blite establishment. Because some trampling is concentrated near sand beaches near public access, transplants may need to be enclosed in poultry mesh cages (if vandalism does not occur), or inconspicuous placement of drift-wood around transplants to discourage patterns of footpaths/social trails. Hybrid smooth cordgrass should be eradicated at this site, and its re-invasion should be precluded by monitoring and spot-control. Sand nourishment of the sand spit and foreshore, following eradication of hybrid smooth cordgrass, should be evaluated and planned to enhance and expand existing suitable habitat. Experimental sand nourishment of Radio Point Beach should be attempted to slow shoreline retreat and produce a berm profile that may support a California sea-blite population. Because beach nourishment here would increase foredune sand accretion, the foredunes should be restored with sufficiently dense cover of native dominant vegetation (*Leymus mollis*, *Ambrosia chamissonis*, *Fragaria chiloensis*, *Atriplex leucophylla*) before sand nourishment is commenced.

4.1.2. Roberts Landing beach, San Leandro, Alameda County

Location: bay shoreline north of San Lorenzo Creek (flood control channel) mouth (Figures 13, 20-23).

Property ownership/management: City of San Leandro.

Prevailing land uses: open space within San Leandro Shoreline Marshlands Enhancement Project (172 acres; salt marsh east of beach), City of San Leandro

Public access: Levee trail from end of Lewelling Boulevard; storm-damaged levee access point at proximal end of beach was closed (fenced, posted notice) by the City of San Leandro circa 2004.

Existing habitat and vegetation: Backshore: Sand beach (former sand dunes), low washover terrace, sparse high salt marsh and beach vegetation; tidal salt marsh (pickleweed dominance) with choked tidal flows landward. Foreshore: sand and mudflats, grading southward to dense, wide hybrid smooth cordgrass marsh in tidal flats of San Lorenzo Creek delta.

Site description:

Physical setting: Roberts Landing beach is derived from a naturally regenerated sand spit that supported low mobile sand dunes in the 1970s. The beach and dunes were subject to intensive recreational uses in the 1970s and 1980s that severely damaged vegetation cover. (Janice and Frank Delfino, Castro Valley, pers. comm.). Sand is well-sorted, fine-medium, and rich in quartz (mineralogically mature, reworked). The probable sand source is intertidal and subtidal sand shoals associated with erosion of submerged Merritt sands (related to Pleistocene Colma, Merced formation, shallow marine, lagoon, beach and dune deposits). Some sand may be supplied by San Lorenzo Creek. Sand supplies appear to have diminished by the early 1990s, when most of the beach became a washover terrace with minimal dune cap (P. Baye, pers. observ.).

The barrier beach today remains is transgressive, migrating landward over salt marsh by overwash, onshore eolian sand transport, and shoreline retreat. In the early 1970s and 80s, the foreshore was unvegetated, and waves actively reworked beach sediments throughout the length of the sand spit. By the early 1990s, the intertidal flats around the distal (south) end of the sand spit developed multiple colonies of non-native smooth cordgrass (*Spartina alterniflora*). By the late 1990s, hybrids of smooth cordgrass colonized and dominated the distal (south) end and tidal flats around the spit, and causing most of it to stabilize as high marsh vegetation (Figure 20). Discrete hybrid cordgrass marsh colonies currently act as tombolos that affect longshore sand transport like groins, intercepting and accumulating sand updrift, while starving downdrift (southerly) areas of sand. Consequently, the sand spit has become reduced to a short segment of barrier beach in front of tidal salt marsh. The beach and washover terrace is approximately 5 to 20 meters wide. The current length of the sparsely vegetated washover terrace is approximately 300 m.

Eradication of hybrid cordgrass marsh at Roberts Landing is proposed by the Invasive Spartina Project (www.spartina.org; California Coastal Conservancy), following completion of ongoing research by the University of California, Davis (D. Ayres). Eradication is forecast to be largely complete by 2009. Thus, the long-term condition of the beach (currently expected) is reasonably likely to become active sand beach again, subject to long-term erosion and landward migration.

The future length of the beach is difficult to forecast because it is affected by variable, unquantified rates of alongshore sand transport and undetermined nearshore sand supply.

Habitat and vegetation: Dominant cover of the active washover terrace (high beach above normal tides) is bare sand, organic debris (tidal litter), and seasonally variable vegetation cover between about 5% to 30% (subjective visual estimate, long-term observation ground and aerial photos, field surveys). Cover in winter is dominated by bare sand and tidal litter. Tidal litter is composed mostly of hybrid cordgrass shoots, woody debris, algae, and fine organic detritus. The proportion of vegetation cover in spring and summer is variable, but is generally sparse, much less than 50% on most of the beach. Vegetation on the washover terrace is dominated by *Distichlis spicata*, *Cakile maritima*, *Ambrosia chamissonis*, and local variable intermediates (likely introgressant) with *A. psilostachya*. A single remnant colony of *Leymus mollis*, the native beach and dune grass, persists on a stabilized segment of the beach. Mature clumps of *Grindelia strica* persist on portions of the beach, but these appear to be relicts rather than actively recruited. Invasive non-native *Salsola soda* is present, and its abundance is expected to vary among years; to date, it has not dominated the beach. At the south end, in the sheltered lee of hybrid cordgrass marsh, the washover terrace is completely covered by either tidal litter (thick wracks of coarse woody debris and cordgrass litter) or high salt marsh and stable beach vegetation. Vegetation here is dominated by *Distichlis*, and local patches of *Cortaderia selloana* and *Arundo donax* (invasive coarse grasses) are present.

Juvenile California least terns have been reported roosting on the beach (Janice Delfino, pers. comm.). One adult male western snowy plover was observed on the beach March 4, 2006 (P. Baye, unpubl. data). Large numbers of migratory shorebirds (marbled godwits, willets, sandpiper, dunlin, etc.) seasonally forage on the adjacent tidal flats and temporarily roost on the sand beach foreshore and washover terrace during high tide stages. Raccoon tracks are present on the beach.

Evaluation: Roberts Landing is the largest naturally formed sand beach in the East Bay south of the Bay Bridge, and the largest suitable habitat for reintroduction in the San Francisco Estuary. It has the potential to support a larger dynamic and persistent population of California sea-blite than any other site known. It is close to the last reported locality of native California sea-blite in San Francisco Bay (Table). Tidal litter deposition and storm/calm beach dynamics appear to be suitable for semi-open perennial vegetation, with sufficient periodic disturbance for seedling colonization and restriction of competition by high salt marsh vegetation. Existing land uses are compatible with reintroduction, and the site is already used at least occasionally by federally listed wildlife (western snowy plover, California least tern), other sensitive wildlife species (migratory shorebirds) and regionally declining or uncommon native plants.

Site-specific reintroduction: Most of the washover terrace supports suitable transplant microsites. No site preparation is currently indicated, but some local removal of *Salsola soda* seedlings (if present) may be prudent in a minimum 2 m radius around transplants. *Cakile* seedlings do not pose a significant threat of competition here. Transplant sites should avoid areas occupied by *Distichlis*. Intense storm overwash may destroy young transplants, so founder population transplanting should be phased over two years. Five transplanted colonies, each composed of at least three genetic individual plants each (up to 5 each; minimum total 15, maximum 45) should be reintroduced in the first year. At least one colony should be located at the south end of the beach, in the transitional area between open sand washover/beach habitat and

closed high marsh vegetation and dense wracks on stabilized beach ridges. If first-year transplants survive by the beginning of the second growing season, additional colonies should be transplanted to meet a total founder population size of 40 to 50 plants. Transplanting methods are described in Section 3.2.

Future potential management actions: Without eradication of hybrid smooth cordgrass, the beach would over time become assimilated into stabilized salt marsh with lower potential for long-term persistence and regeneration of California sea-blite. The sand spit should be maintained to be free of significant foreshore colonies of non-native cordgrass. Hybrid smooth cordgrass its re-invasion after eradication should be precluded by monitoring and spot-control. Invasion by *Salsola soda* should be monitored and removed if it becomes sufficiently abundant to interfere with seedling colonization by California sea-blite. This action is compatible with other habitat values, such as shorebird conservation. Sand beach nourishment (addition of suitable volumes and texture of Merritt sand from local dredge sources) should be assessed and planned to extend the geomorphic life of the beach as sea level rises, and to expand the area of suitable habitat of California sea-blite and other sensitive species using the estuarine beach habitat.

4.1.3. Berkeley Eastshore State Park beaches, Berkeley, Alameda County

Location: Multiple; vicinity of Gilman to Ashby exits along frontage road parallel with I-80, west of Aquatic Park, Berkeley; focal examples are near University exit; Figures 24-26).

Property ownership/management: Eastshore State Park (East Bay Regional Parks District).

Prevailing land uses: low-level local recreational use, mostly recreational fishing; scenic viewing, wildlife watching, walking/hiking (paved trail above beach).

Public access: Improved bayshore trail on sidewalk between frontage road and boulder rock slope protection above beach.

Existing habitat and vegetation: Sand beach with open fetch to west (facing Golden Gate); eelgrass/algal drift-lines (Figure 24); annual and perennial beach vegetation (*Cakile*, *Ambrosia chamissonis*) from high beach and incipient foredunes climbing into boulder rock slope (Figure 24); intermittent erosion. No terrestrial transitional habitat (frontage road). A low-energy south-facing pocket beach and salt marsh ecotone has formed within a former landfill area near University Avenue (Figure 26). Some deposition of algal and eelgrass litter occurs.

Site description: The beach is a natural deposit of wave-reworked Pleistocene beach and dunes sand (submerged Merritt sands) along the historic alignment of Fleming Point sand spit, a large historic West Berkeley beach. The profile is gently sloping and dissipative, exposed to open wave fetch towards the Golden Gate. At the south end (near Ashby), where the shoreline curves slightly towards the northwest, the beach profile widens slightly, and the backshore (boulder slope) becomes accretionary. The segment of beach that periodically develops an accretionary berm profile is approximately 150 to 200 m long. There is some annual and sometimes perennial beach vegetation, but the berm is periodically eroded by storm wave erosion. The berm profile was lacking in October 2005. When the berm profile is present, a low foredune ramp and incipient foredunes form from the toe of the boulder rock slope, to near its crest. *Ambrosia chamissonis* is

abundant during accretionary beach phases, and *Cakile maritima* dominates during both erosional and accretionary phases. Eelgrass drift-lines deposit on the beach. Interbedded eelgrass litter and sand are trapped in the interstices between boulders (Figure 25). The sand-filled interstices are normally stabilized by boulders, and are seldom eroded away. *Cakile* and *Ambrosia* are usually present in the boulder slope.

The south-facing pocket beach, less than 100 m in length, occurs near University Avenue. It is composed of fine quartz-rich sand and coarse woody debris at the high tide line, deposited over high salt marsh dominated by saltgrass (*Distichlis spicata*) and a small low-growing colony of hybrid smooth cordgrass (Figure 25). This site is relatively isolated from pedestrian access and is currently not suited for public access.

Evaluation: The Eastshore beach is partly analogous with two California sea-blite localities in Morro Bay: the Morro Harbor (boulder-armored) shoreline, and the Morro Bay sand spit habitats. The boulders provide effective permanent substrate stability, and are likely to prevent complete undermining and erosion of California sea-blite transplants. The toe of the boulder slope is probably close enough to the water table near sea level to support California sea-blite growth. The local rate of aeolian sand accretion may be exceed the tolerance of young sea-blite transplants when the beach berm is in full profile, but this is unlikely to occur in spring months most years. The widespread natural establishment of *Cakile* and *Ambrosia* in the boulder rock slope indicates that trampling does not preclude establishment of young perennial seedlings. The potential for establishing sea-blite transplants here is greater than potential for natural recruitment of sea-blite seedlings. The lack of a stable high beach largely precludes a beach population of sea-blite, but the boulder slope may provide a permanent refuge. Along the larger Eastshore State Park shoreline, however, there are numerous small pocket beaches and rock slope infill areas that provide small potential seedling habitats. The inaccessible south-facing pocket beach with a high salt marsh ecotone (drift-lines, saltgrass) near the frontage road south of University Avenue is a potential site for either natural seedling recruitment of sea-blite, artificial transplanting, or both. The Eastshore beaches could be developed as a single source population with potential recruitment sites of sea-blite, or multiple local reintroductions. Because prevailing recreational trail and beach uses do not interfere with vegetation (and vice versa), the reintroduction of sea-blite may be compatible with land uses and policies, as at Pier 98 and Pier 94, San Francisco.

Site-specific reintroduction: The segment of shoreline where California sea-blite may be established by transplanting is at the south end of the beach, near Ashby Avenue. Transplant microsites must be assessed by trial-and-error excavation of sand and tidal detritus in gaps between boulders near the high tide line. Suitable planting sites may be guided by the current-year distribution of large (nonnative) *Cakile* plants among boulders. Established non-native *Cakile* may be removed and replaced with California sea-blite. Plants should be unmarked rather than protected with flags or mesh or signage that may attract vandalism. Because risks of mortality due to sand burial, trampling, and summer desiccation are size-dependent, transplants here should be fertilized with a high nitrogen fertilizer solution in spring and early summer. A target founder population size for this site would be approximately 7 to 12 plants. Clustering of transplants (groups of 3 to 5, 1 to 2 m apart, along the high tide line) is recommended, but the feasibility of clustered plantings may depend on availability of suitable planting microsites among boulders. Principal mortality risks here would include erosion and post-transplant desiccation before taproots are established. Trampling appears not to interfere with growth and establishment

of sea-rocket and beach-bur (pedestrians appear to use rocks for footing to access the beach), and so trampling may also be a low risk for sea-blite.

The pocket beach near University Avenue could be developed as a reintroduction site of about 15 to 20 transplants in clustered dispersion. Transplants would be subject to mortality due to heavy storm deposition of coarse woody debris some years. Transplants would need to be cut into established sparse turf of saltgrass (*Distichlis*). Saltgrass turf is likely to cause some root competition with sea-blite, particularly if nitrogen fertilizer is added. Optimal transplant microsites may be barren gaps exposed after storms redistribute coarse woody debris.

Future potential management actions: No ongoing management or maintenance activities are prescribed for this site after transplants are established. During establishment (first two growing seasons), excessive seedling density of *Cakile* or *Salsola* should be controlled around transplants.

4.1.4. Brisbane gravel barrier spit (Candlestick spit), Brisbane, San Mateo County.

Location: Brisbane, San Mateo County, south end of Harney Way (Candlestick Point), east of Highway 101 Bayshore Freeway, between the visitor pull-out area and drainage culverts (flapgates) discharging to the bay under the highway (Figure 27). The location is immediately south of San Francisco County line. The site is very close to the historic Visitacion Bay marshes where California sea-blite historically occurred (Brandege 1892).

Property ownership/management: California State Parks, Candlestick Point State Recreation area. The south end of the spit is the southern border of the Candlestick Point State Recreation area

Prevailing land uses: State Park lands. Minimal visitor use, as indicated by extremely low trampling pressure on vegetation, scarce footprints on gravel spit. Major gull roost is established at the north (distal) end of the gravel spit.

Public access: Road access from Harney Way; exit off Highway 101 or through Candlestick Point State Recreation Area.

Existing habitat and vegetation: Gravel and shell barrier spit with backbarrier salt marsh. Salt marsh is tidally choked by gravel shoals at tidal inlet, and is heavily invaded by hybrid smooth cordgrass. Dominant perennial vegetation on crest of gravel-shell spit is mostly a dense, largely continuous stand of robust *Grindelia stricta* var. *angustifolia*. Dominant beach vegetation is *Salsola soda*, *Atriplex triangularis*. *Foeniculum vulgare* (fennel) and *Carpobrotus edulis* (iceplant) locally dominate the updrift (south) end of the spit. The foreshore consists of rubble and intertidal mudflats, occupied by large flocks of diving ducks in fall and winter.

Site description: The gravel and shell spit is formed by a composite of artificial and natural sediment sources: gravel eroded from artificial bay fill along the bayshore freeway, and shell fragments eroded from natural tidal flat deposits (Figure 27). The spit is recurved, approximately 300 m in length, and encloses a small salt marsh. The crest of the spit is composed of an older higher-elevation inner gravel ridge, dominated by a relatively continuous “hedge” of *Grindelia*

stricta var. *angustifolia* (Figure 27c). The proximal (attached) end of the spit is locally dominated by fennel (*Foeniculum vulgare*) and iceplant.

The gravel berms, closely spaced, form a descending series of younger ridges toward the bay. The spacing between ridge crests widens toward the distal (downdrift, north) end. Grain size of sediment also becomes fine gravel and coarse sand, with a lower beach slope, at the downdrift, recurved end (Figure 27b). The younger, outer gravel ridges are mostly dominated by annual *Salsola soda* and *Atriplex triangularis*, with occasional young *Grindelia* and *Atriplex leucophylla*. The foreshore is gravel and rubble, exposed to intermittent high wave energy from southeasterly storms. The high-energy foreshore is currently free of hybrid smooth cordgrass that is abundant in the sheltered backbarrier marsh. The narrow, erosional updrift (south) end of the spit, and widening of multiple ridges at the downdrift (north) end of the spit suggests that it is “swiveling” to reorient to dominant wave approach, internally redistributing beach gravel and shell, rather than undergoing net growth or erosion. The spit appears to have a very limited local supply of mobile coarse-grained sediment.

Evaluation: The presence of *Atriplex leucophylla*, and abundance of vigorous *Grindelia stricta*, indicate that there is enough fine sediment within the gravel-shell matrix of the spit to support high salt marsh vegetation, including California sea-blite. The crest of the spit is at most 1 meter above the level of the adjacent backbarrier salt marsh. The local groundwater lens beneath the spit is probably variably fresh to brackish and at approximately the elevation of the adjacent salt marsh. The high frequency of *Atriplex triangularis* and *Salsola soda* on the outer beach ridges (formed in the current year) indicate that Amaranthaceae species with similar seedling establishment requirements as *Suaeda* species can readily establish on the coarse-textured beach sediments present. This site is relatively close to Pier 98 and Pier 94 San Francisco (3 to 4 km northeast), and could establish three seed parent populations very close to historic San Francisco localities of California sea-blite, and near potential small, local receptive shoreline habitats around Candlestick Point.

Site-specific reintroduction: The spit should be prepared for transplanting by manually removing the current-year cohort of annual *Salsola soda* from the outer beach, or at least from the vicinity of transplants. California sea-blite transplants should be located at the landward, interior edge of the *Salsola/Atriplex* zone of the beach (identified by distribution of dead annual plants in winter and emerging seedlings. Extra compost and fine sand should be backfilled in large planting holes, compared with standard planting procedures for fine-medium sand habitats. Six colonies (clusters) of three to five transplants should be distributed along the entire length of the spit, with at most one colony at the downdrift recurved end. The recurves are the most receptive shoreline habitat for sea-blite seedlings, and a minimum amount of space should be allocated to founder plants there. Seed dispersal patterns are expected to proceed south to north, aligned with longshore sediment transport direction.

Future potential management actions: Habitat expansion by providing additional sediment with similar textural range may be evaluated, but the potential to enlarge the spit may be constrained by the need to maintain the drainage of the flapgates under the freeway. Further northward progradation of the spit may cause flapgates to choke with coarse sediment, depending on the orientation of further spit recurve growth. The abundance of *Salsola soda* may need to be controlled to prevent excessive interference with seedling establishment of California sea-blite.

Hybrid smooth cordgrass should be eradicated here to prevent the foreshore at the distal end of the spit from being captured by cordgrass marsh, which would stabilize the beach ridge and make it unsuitable for persistence of California sea-blite.

4.2. TIER 2: Potentially feasible sites with modification or further study

4.2.1. Pier 98 San Francisco shell/gravel beach expansion

Location: Pier 98, San Francisco (Heron's Head Marsh; Figures 1, 28)

Property ownership: Port of San Francisco.

Site Description: Pier 98 is an artificial urban port fill peninsula with a boulder/rubble shoreline. The interior rubble flats have accreted bay mud and developed patches of salt marsh (see Section 1.2.2.). Finer gravels winnowed from the rubble fill by wave action have deposited as sheets or beach ridges at the exposed eastern end of the peninsula (Figure 28). Gravels contain interstitial sand and fine sediment. When they temporarily stabilize enough for vegetation to establish, they support high salt marsh plants (*Grindelia*, *Distichlis*, *Salsola*, *Sarcocornia*, etc.). A small shell beach ridge has developed naturally along the sheltered southwestern corner (California sea-blite colony site; Section 1.2.2; Figure 28). The shell beach sediment source (erosion of local bay mud outcrops with high concentration of shell fragments) is very limited and is becoming depleted. The shell beach is erosional, and the bay edge of the beach is reduced to a scarp in bay mud/shell deposits. The local erosional sources of shell (bay mud outcrops, scarps) are limited.

Evaluation: The pattern of local pocket gravel and shell beaches indicates sites of deposition and grain sizes appropriate for local wave energy levels. The sources of gravel are artificial and limited. The irregular configuration of the shoreline provides local traps for coarse sediment transport alongshore (pocket beaches). Beach nourishment with gravel and coarse sand within the textural range of sediments deposited in local beaches would allow beach ridges to accrete and temporarily stabilize between major storm events. Accreted, nourished beach ridges would provide additional potential habitat for California sea-blite colonies. Nourishing the shell beach ridge (and scarped, eroding bay mud foreshore seaward of it) with sand would increase the size and persistence of this beach ridge, increase the viability of the sea-blite population, and increase the potential for its spontaneous expansion by seedling colonization.

The sand refining facility at Pier 94 produces non-commercial "screenings" (waste gravel, shell, and silty sand removed from dredged bay sands) from its industrial sand-sorting processing plant. Selective placement of "screening" gravel/sand at Pier 98 shoreline segments would be a potentially feasible method of expanding California sea-blite habitat here. Placement of "screening" gravels at the outer Pier 94 rubble shoreline resulted in rapid wave-reworking of the deposit into a stabler or accretionary beach ridge with natural form. Nourished beach ridges with intermittent stability (sufficient to enable sparse *Grindelia* to establish) would facilitate establishment of additional transplanted sea-blite populations.

4.2.2. India Basin Open Space Beach, Hunters Point, San Francisco

Location: South India Basin (opposite south Pier 98/Heron's Head Park), Innes Avenue/Hunters Point Boulevard, San Francisco (Figure 29).

Property ownership/land use: presumed City of San Francisco Department of Parks and Recreation. Open Space.

Site Description: Fringing northeast-facing sand beach, sheltered (short fetch, not open to open San Francisco Bay fetch, relatively low wave energy) within India Basin embayment. The beach has prograded (grown into the bay), forming high salt marsh flats below the road. The beach itself grades from high sandy salt marsh (south) to low foredunes (encroaching pickleweed, alkali-heath) at the north end (Figure 29). High beach vegetation includes *Atriplex prostrata*, *Distichlis*, *Frankenia*, *Jaumea*, *Grindelia*, *Salsola*.

Evaluation: This beach is a potential site of colonization by California sea-blite, either by direct transplanting or seed dispersal from a larger Pier 98 population. Because the site is an urban sand beach, attractive for recreation (unlike rubble and gravel of Pier 98), it may have potential future land use conflicts with active reintroduction. Future land use plans for this beach are not known. Current levels of public access and recreational use are apparently low, and trampling pressures are sufficiently low to allow for widespread colonization of the beach by drift-line and high salt marsh vegetation. If this pattern continues, it may be a long-term suitable site for either passive or active reintroduction. A transplant population of about 20 individuals may be established in beach vegetation gaps near established high marsh and low foredunes.

4.2.3. South Brisbane Lagoon, Brisbane, San Mateo County

Location: south end of Brisbane Lagoon, west of Van Waters and Rogers Road and Caltrain railroad line, east of Sierra Point Parkway, northwest of Sierra Point. Northeast end of San Bruno Mountain.

Property ownership/Land Use: Unknown; likely municipal land with no formal open space designation; relatively inaccessible due to railroad (no public crossing) and marsh.

Site Description: The lagoon is artificial, originating as an unfilled diked portion of the historic Visitacion (Gualalupe) Bay and valley wetland complex (riparian wetlands grading into tidal marsh and barrier beach). Erosion and redeposition of some original sediments have regenerated salt marsh and small sand, gravel, and shell beaches within the lagoon (Figure 30). The lagoon has damped tidal range (less than 1.0 m). The south end of the lagoon is downwind of the dominant wind (and wave) direction and has no outlet to the bay; it is therefore sink ("dead end" trap) for transport of sediment and seed dispersal. The lagoon is not supplied with new sediment for net accretion. The lagoon has enough tidal range to support invasion of hybrid smooth cordgrass, which has been spreading in the lagoon since the mid-1990s and may fully colonize its edges if it is not eradicated.

Evaluation: Suitable beach-salt marsh ecotone habitat for a California sea-blite colony exists locally on the southwest shoreline. Beaches sediments are derived from local erosion sources, and

are limited. Beaches may be maintained by wave action (local erosion, deposition). The beach segment shown in Figure 30 could support a small (9 to 12 transplants) but potentially persistent sea-blite colony. A sea-blite colony here, however, would have effectively no (dispersal) connection to any other San Francisco Bay habitat or population, and would be totally isolated. Although the site is isolated, the damped tidal lagoon habitat sheltered and buffered from bay storm waves and sea-level rise; therefore it is potentially more stable relative to all the other fully tidal, exposed open bay reintroduction sites. It may therefore have some value as a stable population refuge for sea-blite. Site stewardship may be problematic because of physical hazards of access (railroad line, marsh with no trails). The lack of access, conversely, may be an advantage for long-term conservation. Long-term conservation benefits for sea-blite would depend on eradication of the spreading existing hybrid smooth cordgrass population in the lagoon.

4.2.4. Crown Beach (east end), Alameda, Alameda County.

Location: East end of Robert Crown Memorial Beach, Alameda, at end of Broadway Avenue.

Property ownership/Land Use: East Bay Regional Parks District. Open Space, recreation, wildlife conservation (Elsie Roemer Marsh).

Site Description: Crown Beach is an artificial beach constructed from sandy dredged materials in the 1960s. The location of the beach is in a region of the bay where sand barrier beaches historically occurred naturally, and the site is very close to Bay Farm Island, the major historic collection locality of California sea-blite in San Francisco Bay. The majority of Crown Beach is subject to intensive trampling from designated recreational use and is therefore unsuitable as a reintroduction site for California sea-blite. The southeastern end, however, supports a sheltered transition zone between salt marsh (Elsie Roemer Marsh; currently dominated by hybrid smooth cordgrass, but programmed for intensive eradication beginning 2006) and sand beach. Large wracks of hybrid cordgrass litter as thick rafts in the high marsh zone. The shoreline segment currently suitable for sea-blite is less than 50 m long.

Evaluation: The southeastern end of Crown Beach/Roemer Marsh receives almost no trampling pressure and is not designated or attractive for recreational use. There is currently enough space available in this non-recreational area to support a local colony of California sea-blite founder population, but not enough space locally to support a self-sustaining population including seedling colonization sites. The founder population may, however, provide a seed source for more diffuse colonization of shorelines around San Leandro Bay (e.g. in rip-rap shoreline). Following eradication of hybrid smooth cordgrass, this would be a highly appropriate potential reintroduction area (vicinity of Bay Farm Island historic locality), despite the paucity of natural habitat. Thus, eastern Crown Beach may have value as a seed source population. Currently, the dominance of hybrid smooth cordgrass marsh in the adjacent intertidal zone makes near-term reintroduction activities inexpedient.

4.2.5. Foster City Beach Park, Foster City, San Mateo County

Location: Vicinity of Belmont Slough mouth, southeast of Beach Park Boulevard and Foster City dredge disposal ponds, Foster City, San Mateo County, on shore of San Francisco Bay.

Property ownership/Land Use: City of Foster City; open space, recreation

Site Description: The nearshore flats west and south of Foster City contain extensive beds of fossil native oyster shell fragments that are subject to wave transport and deposition as fringing shell hash beaches with variable proportions of sand (Figure 31). The beach ridges and foreshore flats are becoming colonized by rapidly spreading stands of hybrid smooth cordgrass. The beach ridges that remain exposed to natural shell sediment transport and wave reworking are capped with high salt marsh vegetation (*Grindelia*, *Sarcocornia*, *Salsola*, *Distichlis* dominant), despite recreational use of the beaches. The shell beaches are extensive (over 1 km length) but the remaining segment of active beach unaffected by cordgrass stabilization is declining. As hybrid cordgrass spreads over the foreshore, the beaches stabilize as dense, closed *Grindelia*/*Distichlis*/*Sarcocornia* (high salt marsh) vegetation, unsuitable for sea-blite reintroduction. Because of short-term variation in beach vegetation, the site should be re-inspected no more than one year prior to initial site feasibility planning to verify suitability of habitat.

The north shore of Foster City (Figure 31) contains highly active, unstable beach ridges exposed to high wave energy (long northeast fetch). The beach ridges are usually over 200 m long, but vary in size following storms. These erosional north-facing beaches tend to support only annual vegetation or sparse hybrid cordgrass. They are not expected to be suitable for California sea-blite reintroduction unless they are nourished with significant additional sediment sufficient to form a barrier beach in front of the flats. Suitable sediment could include dredged coarse to medium bay sand or gravel “screenings” sorted from dredged sand deposits.

Evaluation: The shoreline habitat at the southeastern shore of Foster City contains multiple beach ridges suitable for reintroduction of California sea-blite. The site is also within the historic range of The site is potentially one of the largest shell beach systems with suitable habitat in the Bay, but is in rapid decline because of hybrid cordgrass invasion. In addition, the site is directly adjacent to a large urban residential population that places high value on traditional public recreational access. Even if California sea-blite reintroduction does not impose any restrictions on public access, local public perception of endangered species conservation requirements in the vicinity has been affected by recent controversies. These include Redwood Shores controversy over public access on levees adjacent to the U.S. Fish and Wildlife Refuge, and dredge disposal conflicts with endangered salt marsh harvest mouse habitat within Foster City. The eradication of Foster City hybrid cordgrass invasion has not yet been initiated.

Reintroduction of California sea-blite here in the near term is not feasible because it would require (a) thorough and effective public outreach and agreements with Foster City; and (b) prior completion of hybrid cordgrass eradication on adjacent flats. In the long-term, however, the Foster City beach site would be a very important and large potential habitat and population for regional reintroduction. Based on the ongoing colonization of shell beaches by native high marsh vegetation, it is unlikely that reintroduction success of California sea-blite would require significant restriction of public access. Temporary and local mechanisms of trampling deterrence, undetectable to the public, may include placement of woody debris and brush around founder transplants, rather than conspicuous fencing and signage perceived as hostile to social values of traditional beach use.

4.2.6. Redwood Point and East Bird Island, Redwood City, San Mateo County

Location: Northeast Redwood Shores, fringing tidal salt marsh with shell beach ridges at mouth of Steinberger Slough, and east end of Bird Island

Property Ownership: California Department of Fish and Game and U.S. Fish and Wildlife Service, Don Edwards San Francisco Bay National Wildlife Refuge. Wildlife refuge; no public access; physically inaccessible except by boat.

Site Description: Shell beach ridges naturally deposit along the outer east-facing edges of the salt marsh fringing outer Redwood Shores and Bird Island, supplied by the same series of fossil oyster shell beds that supply the southeastern Foster City shoreline. These are usually vegetated and stabilized by *Grindelia* and *Sarcocornia*, with limited areas of mobile coarse sediment, but erosion and vegetation here are dynamic. The size of the high marsh shell berms and beaches varies around 50 to 100 m.

Evaluation: This site has potential for only a small colony of California sea-blite because of the limited extent of suitable habitat. A maximum size mature colony here may reach a size of up to 30 to 50 plants. Competition with gumplant may restrict population size unless shell sediment supply or erosion/accretion dynamics increase. It may, however, have some viability if planned in conjunction with a feasible reintroduction at Outer Bair Island (feasibility uncertain; see below).

4.2.7. Outer Bair Island, Redwood City, San Mateo County

Location: North Bair Island, near mouth of Steinberger Slough, Redwood City, San Mateo County.

Property ownership/Land Use: U.S. Fish and Wildlife Service, Don Edwards San Francisco Bay National Wildlife Refuge, California Department of Fish and Game; wildlife refuge. No public access.

Site Description: Shell beach ridges naturally deposit along the outer edges of Bair Island near the same fossil oyster shell beds that supply the southeastern Foster City shoreline. Wave exposure is higher here due to longer fetch to north and northeast. Excessive mobility of shell sediments on beach ridges limits the extent of stable high salt marsh vegetation, and much of the beach is unvegetated or seasonally vegetated with annual *Salsola*, *Atriplex triangularis*, etc. Some growth of shell beaches into relatively sheltered positions may support some persistent high salt marsh vegetation sites and suitable sites for colonization. The site is accessible only by boat, and requires a high level of effort for surveys. The length of shell beach ridges is variable, but cumulatively may approach several hundred meters.

Evaluation: The western edge of the shell beach system here may contain some currently suitable sites for persistent populations of California sea-blite. The site should either be monitored for a 3 to 5 year period to observe dynamics of beach vegetation, or experimental plantings of sea-blite should be used as “phytometers” (direct sacrificial test plantings) to assess feasibility before a full-scale reintroduction effort is launched. The Refuge setting makes this a potentially suitable

and valuable reintroduction site if physical conditions prove to be feasible, and particularly valuable if a Redwood Point colony of sea-blite is established nearby.

4.2.8. Whittell Marsh, Point Pinole, Contra Costa County

Location: Point Pinole Regional Shoreline, northeast of the end of Point Pinole Road, along bay edge.

Property Ownership/Land Use: East Bay Regional Parks District; wildlife conservation, public access, passive recreation.

Site Description: Whittell Marsh is a remnant pre-historic tidal salt marsh with a rapidly retreating sand/shell/gravel barrier beach (Figure 32). Erosion is amplified by large boat wakes from high-speed ferries year-round. The barrier beach supports a high salt marsh-beach ecotone with variable proportions of disturbed, unvegetated sediment, beach plants (*Ambrosia chamissonis*, *A. psilostachya* and intermediates; *Cakile maritima*), estuarine gravel shoreline plants (*Iva axillaris*, *Cressa truxillensis*) and high brackish marsh plants (*Grindelia stricta*, *Distichlis*, *Sarcocornia*, non-native invasive *Lepidium latifolium*). The declining length of shoreline supporting potentially suitable California sea-blite habitat is approximately 300 to 400 m. Invasive non-native *Spartina densiflora* has been largely eradicated from this marsh, but it does re-appear and requires maintenance removal.

Evaluation: Whittell Marsh is near the “San Pablo Landing” locality of California sea-blite location reported by Jepson (1911), but this geographic name is ambiguous (it probably refers to the Point Molate/Point San Pablo peninsula to the south). Thus, Whittell Marsh probably represents a minor range extension (about 8 km) for the reported historic collection range of California sea-blite, across a moderate geographic barrier (Point Pinole). Whittell Marsh is a pre-historic remnant marsh with unusually high and distinctive richness of the high brackish marsh flora, including populations of species (or morphologically distinctive populations) that are otherwise regionally extirpated. Therefore, additional consultation would be warranted before “reintroducing” or introducing California sea-blite here.

On the west shore of Point Pinole, in a shallow arcuate embayment, highly erosional gravel beach and bluff shoreline occurs, and in the past, some of this has supported potential suitable habitat for California sea-blite; the habitat appears to be decreasing in suitability as the pace and intensity of erosion has increased in recent years. Therefore, only Whittell Marsh is currently evaluated, but the west shore of Point Pinole should be periodically re-evaluated.

4.3. Tier 3 Sites: considered but conditionally eliminated from further review

The East Bay shoreline between Roberts Landing (City of San Leandro) and Ideal Marsh (Don Edwards National Wildlife Refuge, north of Dumbarton Bridge, Newark) supports numerous, highly dynamic pocket beaches composed of sand, shell fragments, and fine organic debris. These local coarse-grained marsh berms and low beach ridges in the past were often stable enough to support perennial high salt marsh vegetation. In recent years, they have been modified towards one of two extremes. At one extreme, the rapid spread of invasive hybrid smooth cordgrass has stabilized low ridges and caused them to develop full cover of either massive cordgrass litter

wracks (smothering perennial vegetation, replacing with annual salt-tolerant forbs) or dominant *Grindelia-Distichlis-Sarcocornia* protected from wave erosion by dense, tall hybrid cordgrass marsh. At the other extreme, pocket beaches unsheltered by invasive cordgrass has been subject to intensive storm wave attack and excessive mobility, reducing perched shell beach ridges on salt marsh scarps to annual vegetation, regenerating pre-existing salt marsh (*Sarcocornia-Distichlis*), or unvegetated areas. The intermediate condition of accreted high marsh shell berms and beach ridges with partial vegetation are scarce or absent. The feasibility of reintroducing viable populations of California sea-blite in this vicinity appears to have declined in recent years. This shoreline is also programmed for large-scale eradication of hybrid smooth cordgrass, which increases the uncertainty of the near-term suitability of sites for reintroduction. The evaluation of this shoreline segment of the East Bay for reintroduction should be postponed until after the local completion of hybrid cordgrass eradication.

The northern Foster City, San Mateo County shoreline is also conditionally eliminated from further considerations for reintroductions, for similar reasons. The northeast-facing marshes have been subject to increasing erosion, instability, and invasion by hybrid smooth cordgrass.

Sierra Point, Brisbane, San Mateo County has developed small pocket beaches composed of oyster shell fragments, sand, and gravels derived from eroded bay flats and local fills. The beaches may exceed 50 m at times, but hybrid smooth cordgrass has overwhelmed the foreshore near the beaches. When the hybrid cordgrass infestation in this area is controlled, it may be re-evaluated for suitability as a sea-blite reintroduction site.

4.4. Future Potential Habitat Expansion and Reintroduction

Many potential sites evaluated are “sediment starved” because of artificial shoreline modifications. The expansion and enhancement of local habitat for sea-blite population dynamics is based on increasing the extent, quality, and dynamic stability of sandy high tide line habitat, transitional between salt marsh and estuarine beach. In many cases, artificial nourishment of shorelines with sediment of suitable texture (grain size, composition) would compensate for artificial constraints on sediment budgets, and improve viability of habitats for reintroduced populations of sea-blite.

For the Richmond-Berkeley-Oakland-Alameda shoreline, Merritt sands are the natural source of sediment for estuarine beaches. The Port of Oakland periodically generates very large volumes of dredged Merritt Sand for port deepening projects. Caltrans occasionally generates large volumes of Merritt Sand for bridge reconstruction or repair projects. These sands to date have been treated as bulk fill for either tidal marsh restoration projects in subsided diked baylands far from natural sources of sand (Hamilton Wetland Restoration Project, Novato), or landfill disposal (graving dock disposal behind bulkheads, golf course fill). To date, use of Merritt Sand for estuarine beach nourishment or beach creation projects has not been planned. In the context of regional reintroduction plans for California sea-blite and associated special-status species that utilize or depend on estuarine beach habitats, Merritt sand is a highly valuable commodity with a unique contribution to habitat restoration and species recovery.

The premise of estuarine beach nourishment is that addition of sand to the upper intertidal zone would facilitate passive “self-construction” of suitable sandy high marsh and beach habitat for

California sea-blite. Waves rework (erode, transport, re-deposit) sediment in natural forms and patterns, so engineered beach nourishment projects (direct placement of sand fill above mean high water) is not necessary; profile nourishment emphasizing the intertidal zone is an accepted engineering approach (Nordstrom 2000).

More widespread application of “recycled” (beneficial re-use) of dredged Merritt Sand deposits to nourish or create estuarine beaches in the Central Bay could substantially increase the feasibility of California sea-blite reintroduction success. Dredged sand from the central bay is currently used as unspecialized bulk fill for landfill or general bay wetland restoration, without regard to its unique ecological or geomorphic restoration potential.

Natural oyster shell deposits (fossil and historic) in San Francisco Bay have been depleted as a result of mining for cement processing in the 20th century. Existing intertidal shell shoals, ridges, and backshore beaches should be conserved as shorebird habitat. If shell deposits are dredged incidentally for public works projects (such as seismic retrofits of bridges), the beneficial re-use of shell sediments for beach nourishment would be highly valuable for sea-blite habitat, as well as tern, plover, and high tide shorebird roost habitat.

4.5. Co-reintroductions of associated uncommon or declining species.

At Morro Bay, California sea-blite occupies a very narrow zone in the ecotone (transitional gradient) between salt marsh and terrestrial plant communities (specifically, modern dune and paleodune scrub). The high salt marsh ecotone in which it occurs also supports other regionally declining, uncommon, or rare plants. The modern San Francisco Bay shoreline has an impoverished tidal marsh flora because most source populations species with limited dispersal ability or distribution have been eliminated. Widespread, common species and invasive non-native species compose most recent tidal marsh vegetation. While there is no evidence that the success of California sea-blite establishment depends on any uncommon species, the ecological complexity and context of the new population at Pier 94 would be enhanced by reintegration with natural plant associations. If future opportunities arise to enrich the native species diversity of the substantial local sandy marsh-terrestrial ecotone in which California sea-blite is established, the following information may guide enhancement efforts.

The most specific early historic salt marsh floristic surveys for San Francisco Bay were reported by Brandegee (1892) and Howell *et al.* (1958) for San Francisco. Brandegee (1892) noted specific localities for a number of plants that are narrowly associated with brackish or saline wetlands and shorelines. These localities also sites of historic records of California sea-blite. Many of these species are known from remnant San Francisco Estuary localities, analogous (reference system) habitats in Morro Bay, and Drakes Bay.

These species are recommended as potentially suitable candidates for future co-reintroduction high marsh-terrestrial ecotones, depending on local floristic evidence and local shoreline habitat conditions. The enrichment of native associated species associated with California sea-blite reintroductions may also have the practical advantage of contributing to resistance to invasion and dominance by weedy vegetation (mostly non-native) prevalent along urban shorelines. Non-native invasive plants may otherwise tend to encroach on the valuable high marsh/beach ecotone. Compatible native low-growing vegetation above the California sea-blite zone would help

minimize adverse shade and competition from tall, weedy forbs, grasses, and shrubs, such as *jubata* and pampas grass (*Cortaderia jubata*, *C. selloana*), iceplant (*Carpobrotus edulis*), fennel (*Foeniculum vulgare*), and tall forms of coyote-brush (*Baccharis pilularis*).

The following list is a selection of terrestrial species from salt marsh and terrestrial vegetation adjacent to the California sea-blite zone. The criteria for selection are (a) species lack local source population within reasonably likely dispersal distance (negligible probability of natural recruitment); (b) species was historically reported from southeastern or southern localities of San Francisco flora, or unspecified early historic Central San Francisco Bay shoreline habitats matching them; (c) species is normally found in analogous bay wetland and terrestrial habitats of the central California coast. Detailed information on the location of suitable source populations, propagation, and transplanting specifications is outside the scope of this document.

- *Atriplex californica* (California saltbush). Perennial taprooted prostrate forb, gray-green. Occurs in sandy high marsh and Limantour Estero and Elkhorn Slough. Local marine cliff populations occur in Franciscan bedrock of Golden Gate (Lands End to Golden Gate Bridge), and Pacifica coastal cliffs.
- *Ambrosia chamissonis* (beach-bur), *A. psilostachya* (ragweed), and natural hybrids. Beach-bur is a prostrate, creeping silver-gray silky-haired forb with a deep taproot, native to California coastal dunes and beaches. In San Francisco Bay, it occurs as the typical species and as intermediates with *A. psilostachya*, a moderately salt-tolerant creeping, slender gray-green forb of wetlands and riparian zones. One spontaneous colony of *A. chamissonis* occurs at Pier 94. Apparent hybrid swarms occur along the San Leandro bayshore near Roberts Landing, and along the Berkeley-Richmond-Point Pinole shoreline.
- *Atriplex leucophylla* (seabeach saltbush). Prostrate gray-white subshrub, beach habitats. Historic records in Visitacion Bay shore. Occurs at Radio Beach, Oakland (2005), and intermittently along the San Leandro shoreline some years.
- *Cordylanthus maritimus* ssp. *palustris* (northern salt marsh bird's-beak). Annual low-growing hemiparasitic forb, typically most abundant in organic sand of upper middle salt marsh. Nearest population is north Sausalito; extirpated south of Golden Gate. State-listed; collection of seed and reintroduction requires authorization from California Department of Fish and Game. No federal legal status.
- *Heliotropium curassavicum* (seaside heliotrope). Perennial taprooted gray-green fleshy forb, typically at high tide line in sandy substrates. Nearest populations for Central Bay: Rodeo Lagoon, San Francisco Bay National Wildlife Headquarters (Newark).
- *Iva axillaris* (Poverty weed). Creeping low-growing gray-green perennial forb. Historic records in Visitacion Bay shore. Sandy beach near high tide line. The species is locally abundant on gravel shores of Tiburon (Richardson Bay, Audubon Sanctuary) to San Rafael, and Richmond (Point Pinole).

- *Lasthenia glabrata* (salt marsh goldfields). Annual erect forb. Historic records include Islais Creek, south San Francisco. *L. glabrata* occurs in high sandy salt marsh at Limantour Estero, Point Reyes. No local Central or South Bay source populations; two nearest remnant salt marsh populations are in San Pablo Bay.
- *Lasthenia minor* (goldfields). Annual decumbent forb. Historic records include south San Francisco and Visitacion Bay. No known San Francisco populations; nearest populations occur on central San Mateo County coast, low marine bluffs.
- *Leymus mollis* (Pacific dune-grass). Perennial rhizomatous grass of coastal beaches and low dunes, seeps in sand bluffs; rare in San Francisco Bay. A single apparently natural remnant population occurs at Roberts Landing. (Crown Beach population is apparently introduced.)
- *Solidago confinis* (goldenrod). Extinct in San Francisco Bay; historic records are known from Laguna Honda, San Francisco, and San Francisco Bay salt marsh (*S. sempervirens* misapplied). Nearest tidal marsh population: Morro Bay (brackish high marsh). Also in cultivation.

Another native species co-reintroduction that may benefit California sea-blite reintroduction even more than terrestrial species is eelgrass bed restoration (*Zostera marina*). Eelgrass litter is probably important for the nitrogen nutrition of sea-blite seedlings and mature colonies (see Sections 1, 2), and it may be a potential limiting factor in the growth and reproductive output of reintroduced San Francisco Bay sea-blite populations. Eelgrass restoration feasibility may be facilitated by relatively lower suspended sediment concentrations (turbidity; higher light penetration) in the vicinity of submerged sand deposits associated with some estuarine beaches. For example, eelgrass colonies have been recurring near Radio Beach and Eastshore State Beach, and they are consistently present in the tidal litter there. The complexity of planning shallow subtidal eelgrass restoration may be greater than high tide beach habitats of California sea-blite, but it may be beneficial to consider joint benefits in the context of larger-scale sand placement plans for beach nourishment.

5.0 Monitoring and Adaptive Management

5.1. Monitoring Goals and Objectives of California sea-blite reintroduction.

Following the goals and objectives for reintroduction of California sea-blite, the most basic goals for its monitoring are (a) to quantify and report the fate (survivorship, growth reproduction) of the founder population, and (b) to quantify and report the natural, spontaneous recruitment of multiple seedling generations in restored habitat. These basic goals are independent of higher objectives for research in demography, population dynamics, or population genetics of reintroduction.

The specific monitoring objectives proposed are:

- to quantify founder plant survivorship and growth over a minimum 7 year period, and to roughly estimate their seed production;

- to detect and census seedlings of California sea-blite recruited between (or within) founder transplant “clusters”, and to measure their survivorship, dispersal, and growth within the site over a 5 year period;
- to detect and quantify seed production in a naturally recruited seedling generation;
- to detect any offsite spread of California sea-blite in the project vicinity

5.2. Monitoring approach

Monitoring programs are *presumed to be conducted by trained volunteers*, as part of site stewardship. This assumption is based on foreseeable limited funding for reintroduction projects in recent years, but it should be periodically re-evaluated. Monitoring volunteers are likely to work as teams with significant turnover within a 5 year monitoring period. Methods proposed for monitoring are adapted to a volunteer program, and do not presume disciplinary data collection expertise in plant ecology. The protocols for data collection, and the monitoring data should, however, be sufficient for meaningful interpretation by natural resource agency staff and qualified scientific peer reviewers.

It would be highly advantageous to have the site “adopted” by community college or university instructors for annual student field data collection exercises, or to have the site used for graduate student research. The site offers a rare opportunity for research in rare plant reintroduction within San Francisco Bay.

5.3 Monitoring methods and techniques

The following description of monitoring methods outlines field techniques for data collection. Successful implementation of monitoring methods by volunteer stewards would require training on site by qualified, experienced field biologists, and would require basic plant identification skills. For background on field data collection methods in vegetation measurement, see Bonham (1989) and Elzinga *et al.* (1998).

5.3.1. Sampling shoreline segments (stratification)

Efficient sampling of vegetation requires recognition of distinct sub-units with relatively homogeneous topographic and environmental conditions within them, corresponding to overall vegetation patterns. Vegetation sampling should be subdivided or stratified according to preliminary, distinctive natural boundaries if they exist (Bonham 1989). The Pier 94 shoreline is “naturally” distinguished by sub-units that vary in wave exposure, shoreline orientation, and adjacent vegetation. The shoreline itself is a relatively linear feature, and the natural distribution of California sea-blite is narrowly associated with the high tide zone of the salt marsh or estuarine beach.

5.3.2. Permanent landmarks, benchmarks. If feasible, relatively immobile, permanent markers, such as permanent stakes (or pre-existing modified features such as large rocks) should be established as reference points to mark lines running parallel with each shoreline segment. The distance between permanent reference points can be used to identify and locate data sampling points. Permanent marker locations should be recorded precisely as GPS points, if feasible.

Permanent marker locations can also be used as points and sight lines for fixed-perspective photomonitoring.

5.3.3. Census and growth assessment

Each marked code-labeled transplant should be mapped along transects of each shoreline segment. Transplants unique identity should be identified by (a) shoreline segment; (b) cluster planting position along shoreline and (c) unique seedling identity. In spring (April), summer (July-August) and fall (October), each transplant should be recorded for status as:

Transplant census

- Present/absent (removed)
- Live/dead (100% leafless)
- Rank decline in vigor if over 25% of current-season branch length is leafless (leafless proportion ranks: 25-50%; 51-75%; 76-99%; 100% = dead)

Transplant plant vigor (size, growth rate)

- Length/maximum width of plant (assuming some asymmetry)
- Average height of 3 haphazard/random points within 2 feet of the center of the plant.
- Average shoot length between shoot tip and closest lateral shoot; 3 subsamples of largest branches (an index of growth rate)
- (optional) subjective leaf color description (yellow-green, pale green, gray-green, glaucous [whitish cast] blue-green) OR objective color key chart match

Transplant reproductive status

- Vegetative/flowering/immature fruit/ripe seed state
- Rank % branches with flowers/fruits (0%, 1-25%, 26-50%, 51-75%, 76-99%, 100%); rank semi-quantitative reproductive output
- (optional, labor-intensive seed production estimate) Take subsamples of 3 fruiting shoots per plant; record fruiting shoot length; remove fruits, extract seeds manually, count seeds; estimate number of ripe (black, glossy) seeds per length fruiting shoot. Sample minimum 5 plants if available.

Sea-blite seedling census and growth (assuming infrequent, low density seedling recruitment under 50 seedlings per shoreline segment; over 50 seedlings, apply subsampling method below)

- Measure, record individual seedling occurrence distance along transect (shoreline position);
- Mark and label (inconspicuous marker), record seedling identity, location;
- Measure, record seedling distance from 2 nearest founder transplant clusters (if no seedling-established plants have matured and produced seed); or measure distance to nearest mature plant if first seedling generation has matured to reproduce;
- Measure, record distance from nearest same-year seedling (nearest-neighbor distance)
- (If seedlings occur in aggregates, count number of seedlings in local clustered dispersion and approximate size [length, width] of polygon they define)

- Visually estimate rank % absolute cover of other vegetation, bare substrate, tidal litter within 3 ft of seedling (Daubenmire cover-classes for ease and replicability: trace/present, 0-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%)
- Identify and record plant species within 3 feet of transplant shoot tips;
- Identify dominant 3 species (cumulatively > 50% relative cover), if any, within 3 feet of shoot tips
- **SUBSEQUENT CENSUS AND GROWTH ASSESSMENT** (as for transplants): in census/monitoring periods after initial detection of a seedling, record present/absent, live/dead, length/width, height, flowering/fruitlet status, shoot length above uppermost branch). Each seedling initiates a census/growth assessment data sheet, assuming fewer than 50 seedlings per shoreline segment.

Sea-blite seedling density sampling (multiple sub-samples if seedling population exceeds 50 individuals per shoreline segment)

- Count seedlings within 6 foot intervals between transplant clusters, within shoreline segments.
- If seedling size varies significantly, rank seedlings by either number of branches (number of elongate lateral shoots; unbranched, 1-3 branched, 4-10 branched, >10 branched) or size-classes (maximum width; 1-5 cm, 6-10 cm, 10-25 cm, > 25 cm)

Patch census (long-term)

After more than 5 years, many closely spaced sea-blite plants may sprawl and coalesce into patches within which individual plants may be difficult to distinguish without ongoing maintenance of plant markers, tape, or tags. It can be assumed that negligible seedling recruitment occurs under the canopy of mature plants. When a group of seedlings, founders, or combinations, merge into a single confluent patch, the population size of the patch should be “finally” recorded, and the patch can be subsequently monitored as a single unit. The interpretation of the unit’s fate in terms of population change can be interpreted and analyzed by recording its composition and history for future census work.

5.3.4. Transplant vegetation status

This is an individual plant-based, high-resolution assessment of immediate neighborhood conditions of individual transplants or clusters, rather than assessment of the whole community in which transplants occur. It is particularly relevant for the first several years of establishment.

- Visually estimate rank % of sea-blite transplant perimeter in direct contact with other vegetation (0%, 1-25%, 26-50%, 51-75%, 76-95%, 96-100%) and % bare substrate, % tidal litter.
- Identify and record plant species within 3 feet of transplant shoot tips;
- Identify dominant 3 species (cumulatively > 50% cover), if any, within 3 feet of sea-blite founder transplant shoot tips

5.3.5. Vegetation line-intercept transects

As an optional measurement to quantify the vegetation in which sea-blite occurs, a transect (survey line) can be established along the high tide line zone, centered on sea-blite. At 3 ft or 6 ft intervals (adapt to complexity of vegetation; shorter for more complex species-rich vegetation), length of the transect line that intercepts (contacts) a particular cover type (plant species, organic tidal litter, inorganic debris, and mineral substrate) is measured and recorded (the cumulative length of the interval directly contacting that species or cover type). The line-intercept length of other species occurring as sub-canopy beneath the line may be separately recorded. This technique measures the absolute line-intercept percent cover values, a very accurate measure of vegetation cover. Be careful to keep the line steady and fixed. Line-intercept cover for each shoreline segment transect can be reported separately. Transects of dissimilar environments should not be aggregated.

5.3.6. Qualitative monitoring and description

In addition to quantitative and semi-quantitative (rank) data collection, with each site visit, report overall narrative descriptions of any apparently significant changes to the shoreline segment, such as recent erosion, deposition of drift-lines, expansion of cover by a particular species (such as weeds), indication of vandalism, mass dieback patchy dieback of vegetation, etc. These descriptions supplement photomonitoring and quantitative data as aids for interpretation.

5.3.7. Optional environmental monitoring

These are additional measures that may be useful for interpreting survivorship and growth responses among sub-populations of shoreline segments, or recovery from storm events. They are not recommended for routine measurement multiple annual measurements unless project resources allow.

- *Soil salinity.* Excavate sand beneath center of sample plant to depth of 10 inches. Take a sand sample at depth, hold in plastic and minimally saturate with distilled water. Squeeze 1 drop from sand/water slurry; place on hand-held refractometer or measure with calibrated water quality testing kit. Use the same instrument for repeat measures. Record salinity of saturated porewater in root zone. Recommended sampling: 3 individual plants of each shoreline segment.
- *Relative high tide line position.* Measure the distance between the center (rooting point) of a random subsample of seedlings or matured former seedling-grown plants, and the upper limit of the highest drift-line.
- *Sand burial/erosion markers.* Within the canopy of individual, subsampled sea-blite plants, drive in a permanent stake and mark in permanent paint the substrate surface position. Subsequently measure and record exposure or burial depth (by sand, tidal litter) to monitor substrate surface conditions.
- *Shoreline profiles.* (professional collaboration required). If local benchmarks are available, establish permanent shore-perpendicular transects to quantify beach profile changes (elevation gradient), position of sea-blite in elevation gradient.

5.3.8. Photomonitoring.

Photomonitoring is useful for capturing qualitative comprehensive, complex information about vegetation patterns, vegetation structure, geomorphology, and background changes, as well as incidental information, that would be too labor-intensive to document by focused quantitative monitoring. It is also very useful for communication and explanation of monitoring data to both technical and non-technical readers of monitoring reports (especially executive summaries). Photomonitoring can also be used to “bridge” interpretation of gaps (particularly year-long or multiple year gaps) in monitoring data.

Basic fixed-point, fixed-perspective photomonitoring should be based on sight-lines between local benchmarks or monuments (either “natural”, or permanent artificial ones) and either compass directions or other permanent sight-line (visual transect) targets on site or in permanent view. The basic photomonitoring sight-lines recommended are along the long axis of each shoreline segment, from both ends of the segments. In addition, perpendicular sight-lines (equivalent to elevation transects) may be included from the base of the swash slope to the edge of terrestrial vegetation and one or more intervals of each segment. Incidental photos may also be used to document significant local changes (patches, events) within each segment. Spot-photo location should be identified, when feasible, as distance along each permanent long-axis transect of the shoreline segment. Spot-photos can also be used to record examples of quantitative sampling (e.g. plant size, reproductive status, percent cover estimates, etc., plant identification) for peer review or quality control.

It is preferable to use a camera with a wide-angle lens, and use the same lens for all photos. A 28 mm single lens reflex camera lens (digital or film) is recommended. Digital photography is most efficient for document preparation and transmittal; film photography (color slides) is most reliable for long-term archival storage.

5.3.9. Offsite dispersal and recruitment

If net seed production of the Pier 94 sea-blite population is large, there is some probability that offsite seed dispersal and seedling establishment may occur in receptive shorelines. Local southeastern San Francisco gravel or sand beaches, or high salt marsh areas supporting associated species (gumplant, pickleweed, etc.) should be intermittently surveyed to detect offsite spread of sea-blite from the artificial founder population.

5.4 Frequency and duration of monitoring

Perennial forb and shrub population trends require many years to establish. Regulatory (permit-related) and scientific conventions for monitoring are very different. For meaningful interpretation of population trends, a minimum 5 to 7 year annual monitoring period is recommended for California sea-blite. This is based on long-term observation of California sea-blite populations in Morro Bay and at the two San Francisco Bay reintroduction sites. A customary 3 to 5 year (regulatory) monitoring period of these sites would provide a biased and misleading record of the nature and trends of population dynamics. A 10 year monitoring program is recommended.

If project resources (labor, funding) are limited to a 3 year total monitoring effort, that effort should be spread out over at least a 5 year period, including the first two successive sampling years. If a 5 year monitoring effort is the limit, that effort should be distributed over 10 years (years 1,2,3,5 or 6, 10). Photomonitoring should occur regardless of monitoring budgets. Census of adult breeding population or at least numbers of patches should also occur annually regardless of monitoring budget; this is a minimal effort exercise.

Potentially labor-intensive seedling census surveys may be limited to the first 3 years of the project if seedling numbers are high. If seedling numbers are low (or nil), survey efforts should proceed annually. Seedling sampling should occur at least in the final survey year if monitoring is not ongoing. The final monitoring year should also include vegetation survey data, and sea-blite growth and reproductive status data.

Significant physical site changes, such as intense storm erosion, would strongly indicate a need for additional or modified monitoring to detect mortality and potential post-storm seedling recruitment.

5.5. Reporting

Monitoring reports should report the status of the reintroduced population of sea-blite, describe the habitat conditions, evaluate results in terms of project goals and objectives, and comment on how results compare with conceptual models and assumptions of this plan. The ultimate questions that the final (or earlier) monitoring report should address is whether the reintroduction has resulted in a stable or increasing population, and whether a complete life-cycle (second generation of reproduction after founder population establishment; seedlings of seedlings) has occurred. Changes in the distribution or abundance of sea-blite within the site should also be featured, and evaluated in relation to local environmental conditions.

The reports should summarize or append project history, objectives, and previous monitoring data. Each report should include clear statements of:

- Founder population size and survivorship
- Breeding population size (flowering/mature plant number)
- Turnover (compensatory replanting) of founders
- Seedling population size and distribution (by shoreline segment)
- Seedling dispersal distances
- Total population size and trends
- Plant growth and reproductive output, and trends
- Associated vegetation: species composition, abundance, and trends

Reports should include a description of monitoring methods and any modification of methods or sampling regimes. The names and qualifications of data collectors and report preparers should be included. The names and affiliations or qualifications of any peer reviewers or editors should be acknowledged.

Reports should feature figures composed of photomonitoring results, with stated locations and explanation of key ecological features of each view.

In a focused discussion section, each report should explicitly evaluate the project's results in terms of its goals, objectives and the conceptual reintroduction model.

If possible, reports should be circulated to qualified expert peer reviewers as draft reports, and final reports should reflect comments of reviewers. Final monitoring reports should be submitted to resource agencies with jurisdiction (local landowners and managers) or expertise (California Department of Fish and Game), and offered to interested organizations (e.g. California Native Plant Society).

5.6. Adaptive management

Monitoring data rarely provide conclusive “proof” of any ecological causal factors regarding population change, by scientific standards of hypothesis-testing in ecology. Monitoring data are useful for practical management decisions based on judicious “weight of evidence” evaluations that consider the scientific literature, professional experience, and site-specific conditions. Monitoring results should not be used only to justify further monitoring or research in applied ecological experiments such as reintroductions. They should be applied to actions that are reasonably likely to advance project objectives.

In addition to the transplant-phase adaptive management issues discussed in Section 3.2.5, the most predictable long-term adaptive management actions would be control of invasive non-native competitors of sea-blite, particularly sea-blite seedlings. Most of the central and south Bay is infested with *Salsola soda*, which has both local seed sources and long-distance dispersal from offsite populations. *Salsola* commonly forms dense, closed vegetation in estuarine beaches habitats, and this is likely to interfere with seedling establishment by other species that require drift-lines microhabitats. Early detection of *Salsola* during annual monitoring should trigger (a) seedling removal near plants early in development; (b) removal of other on-site *Salsola* in early flowering stages (early summer) to prevent local seed production. This annual plant is easily removed by hand. Other invasive plants on site may also affect sea-blite, as monitoring may indicate.

Erosion-induced mortality of sea-blite is not readily mitigated. Ample sand placement should buffer erosion by allowing post-storm recovery of the shoreline profile. If the shoreline profile adjustment shifts the high tide line landward of the original sea-blite founder population to a significant extent (i.e. resulting in high initial mortality), a subsequent replanting of founders (salvaged transplants or new transplants) along the more stable adjusted high tide drift-line position would be justified.

Adaptive management decisions (actions other than recommendations for additional monitoring) require sound professional judgment. Monitoring reports should be circulated to qualified individuals who can provide action-oriented, well-informed recommendations about site management in the long term.

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Table 1

**Historic distribution of *Suaeda californica* in San Francisco Bay:
Summary of representative herbarium and flora records**

UC: University of California herbarium (Berkeley). JEPS: Jepson Herbarium (UC Berkeley). CAS (California Academy of Sciences herbarium). DS: Dudley/Stanford herbarium (at California Academy of Sciences). Names in italics are collectors and collector's specimen numbers with year of collection in parentheses. Literature citations are not italicized. Habitat and locality descriptions are transcribed from original herbarium labels or literature cited.

County, locality and collector/author	Most recent date reported	Habitat described
ALAMEDA CO. Bay Farm Island. <i>J.T Howell</i> 19327 (UC, CAS; 1943); <i>H.L. Mason</i> 4944 (UC; 1928); <i>H.E. McMinn</i> 892 (DS; 1923) W.L. Jepson (JEPS; 1891, 1913); <i>H.A. Walker</i> 473 (UC, DS; 1906); <i>W.A. Setchell</i> (DS; 1902) <i>J. Burt Davy</i> (UC 1898); <i>A. Kellogg</i> (UC; 1996)	1943	Salt marsh. U.S. Coast Survey maps of 1850s indicate beach deposits.
ALAMEDA CO. Alameda Marshes. (Locality is generalized description, no boundary; may include Bay Farm Island localities) <i>A. Eastwood</i> 11057 (CAS: 1921); <i>N.L. Gardner</i> (UC; 1923)	1921	Salt marsh
ALAMEDA CO. San Leandro. <i>G.T. Robbins</i> 3944 (JEPS: 1958)	1958	Shoreline of San Francisco Bay, near west end of Williams St, San Leandro
ALAMEDA CO. Oakland. <i>J.W. Congdon</i> (DS; no date, ca. 1880s), <i>V. Rattan</i> (DS: 1880)	1880	[presumed salt marsh]
ALAMEDA CO. "Fleming" (Albany/Berkeley). <i>H.A. Walker</i> 2825 (UC: 1912)	1912	On S.P. railroad line
ALAMEDA CO. "salt marshes on an island near Alameda" (Behr 1888)	1888	"salt marshes"
CONTRA COSTA CO. "San Pablo Landing" (Richmond). Jepson 1911.	1911	"sandy beaches bordering San Francisco Bay"
SAN FRANCISCO CO. Visitacion Bay (San Mateo Co/San Francisco Co) and southeast San Francisco. K. Brandegee 1892.	1892	[shoreline: estuarine barrier beach and salt marsh]
SANTA CLARA CO. Palo Alto. J. McMurphy (DS: 1906); Ravenswood Point Marsh (Zucca 1954)	1954	"back bay", salt marsh
SAN FRANCISCO BAY – San Pablo Landing, Bay Farm Island (Jepson 1911) "Sandy beaches bordering San Francisco Bay, the known stations few"	1911	"sandy beaches bordering San Francisco Bay"
SAN FRANCISCO BAY – "Vicinity of sand beaches about San Francisco Bay but seldom seen" (Greene 1894)	1894	"vicinity of sand beaches"

Table 2

Doubtful records and reports of *Suaeda californica* in San Francisco Bay area

UC: University of California herbarium (Berkeley). JEPS: Jepson Herbarium (UC Berkeley). CAS (California Academy of Sciences herbarium). DS: Dudley/Stanford herbarium (at California Academy of Sciences), SJ (San Jose State University herbarium). Names in italics are collectors and collector's specimen numbers with year of collection in parentheses. Literature citations are not italicized. Habitat and locality descriptions are transcribed from original herbarium labels or literature cited.

Locality and collector, habitat	Evidence of misidentification
"Melrose between Alameda and Concord quad...veg type marsh, slope", H.S. Yates 5933, <i>JEPS</i> 86406 [1936]	inland locality, geographically consistent with alkali sink or pool, suggests <i>S. moquinii</i> .
Mission San Juan Bautista, San Benito County; plant part remnants from adobe bricks of church founded 1797 (Hendry and Kelley 1925)	Identified as <i>Dondia Californica</i> (synonym of <i>Suaeda</i> c.) from traces in bricks, no morphological data for determination given; all other species identified are either agricultural weeds or cultivated crop species, no salt marsh taxa. Non-coastal, interior locality. May be confused with cultivated or weed species of Chenopodiaceae with similar fruit or inflorescence morphology, such as <i>Bassia</i> , <i>Beta</i> , or native annual <i>Suaeda calceoliformis</i> .
Vallejo Rancho near Petaluma, Sonoma County; plant part remnants from adobe bricks in building erected 1834-1835 (Hendry and Kelley 1925)	Identified as <i>Dondia Californica</i> (synonym of <i>Suaeda</i> c.) from traces in bricks, no morphological data for determination given; all other species identified are either agricultural weeds or cultivated crop species, no salt marsh taxa. Non-coastal, interior locality. May be confused with cultivated or weed species of Chenopodiaceae with similar fruit or inflorescence morphology, such as <i>Bassia</i> , <i>Beta</i> , or native annual <i>Suaeda calceoliformis</i> .
<i>Heckard, L.R. with L. Feeney and P. Faber & J. Hickman</i> 5253, <i>JEPS</i> 85406, May 13, 1986. "Mud Slough n of e of SP railroad tracks Fremont e of San Francisco bay, site of proposed airport Fremont – low marshy flats bare saline soil of old marsh". Santa Clara County.	Photograph of specimen has nearly leafless (bracts reduced, smaller than fruits/flowers) terminal inflorescence; locality is non-tidal alkali vernal pool flat supporting seepweed/alkali-blite, <i>Suaeda moquinii</i> (P. Baye, pers. observ 1997; see also McMinn 1939). Likely key interpretation error or reliance on earlier Sharsmith identification.
<i>C.W. Sharsmith</i> 5872, SJ 1128, October 26, 1951. "Abundant locally, side of levee which crossed salt marsh and strongly alkaline levels....c. 5 miles N of Milpitas". Santa Clara County.	Near known non-tidal modern locality of <i>Suaeda moquinii</i> (P. Baye, pers. observ 1997; see also McMinn 1939).

Table 3

**Summary of proposed population and habitat objectives for
California sea-blite reintroduction, San Francisco Bay**

Basic reintroduction goal	To establish a persistent, dynamic reproductive population of California sea-blite at Pier 94, exhibiting spontaneous seedling recruitment and survival, net population growth, in dynamic sandy high salt marsh habitats dominated by native plant species, and with minimal management. (<i>"minimal management" refers to suppression of invasive nonnative plants in the high tide line</i>).
Founder population size objective	Initial local founder population of 30 to 40 plants; minimum breeding population size of 20 individuals over a 5 year period. (<i>This objective may be met by a combination of surviving transplants and naturally recruited plants</i>)
Founder population reproductive objective	To generate a local, self-maintaining seed source for local dispersal and colonization of suitable high tide line (drift-line) habitat within 5 years after transplanting the first founder population.
Seedling recruitment objective	To detect multiple patches of (naturally established) seedlings on the site during the growing season following significant storm events that generate disturbances; at least one seedling cohort (seedling generation of relatively uniform age) within five (5) years should contribute enough surviving individuals to cause net increase in the breeding population at the site.
Long-term reproductive objective	To recruit a second generation of seedlings after the first seedling cohort reaches reproductive maturity and produces mature, viable seed, with net growth in breeding population size (net increase in mature, reproductive individuals) at the time of the second generation of seedling recruitment.
Habitat objectives	Population objectives should be met in association with predominantly native high sandy salt marsh plant assemblages, modified by natural processes. Management should be limited to suppression of non-native competitors (primarily <i>Salsola soda</i> , Mediterranean saltwort).

Table 4

Summary of California sea-blite census of Morro Bay, 1998-2000. Number of established juvenile and reproductive plants, exclusive of seedlings. Sample sites represent local populations separated by significant gaps. (source: P. Baye, original unpublished data)

Morro Harbor/Channel rip-rap shore	15
Heron Rookery/oyster shell beach	7
Museum Beach (Fairbank Point)	55
Pickleweed Island	2
Marina (interior rip-rap shore)	27
Morro State Park entrance marsh	5
Sand spit (main backbarrier shoreline)	191
Los Osos/Cuesta	31
Sweet Springs (Audubon reserve)	12
Baywood Park shoreline	14
Total cumulative estimated Morro Bay population (exclusive of seedlings) 1997-2000	359